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THE GEOMETRICAL INTERPRETATION OF IMAGINARY QUANTITIES.

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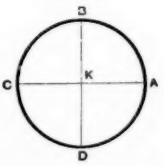
II.

IT is to be observed that while there exists an infinite variety of directed lines, practically they are all referred, as will be shortly shown, to $\overline{KA}$, $\overline{KC}$, $\overline{KB}$, $\overline{KD}$, the position unit being $\overline{KA}$ the negative $\overline{KC}$ and the means $\overline{KB}$ and $\overline{KD}$ (Fig. 4).

Fig. 4.



It is, furthermore, convenient to classify any two opposite directions under one head, to which we shall apply the term *order*. The primitive $\overline{KA}$ with its negative $\overline{KC}$ we shall designate as the *prime order*, and the means $\overline{KB}$ and $\overline{KD}$ as the *medial order*. We shall speak of a *prime quantity* or *medial quantity* when we refer to one of a *prime* or *medial order*, respectively. These terms are derived from the mode of generation of these quantities, and from the conception under which they are regarded real. We might apply the general term *intermedials* to all others which it is not necessary to designate specially.*

8. In accordance with what precedes, we may also modify the language of so-called *imaginaries* in such a way as to render this part of the subject more simple. In writing $+a\sqrt{-1}$ or $-a\sqrt{-1}$, we indicate explicitly the way in which the quantity is generated, which in certain cases may be useful; but ordinarily we leave the mode of generation out of consideration, and $\sqrt{-1}$ is only a particular kind of unit to which the number a is referred. It is, therefore, not absolutely essential to keep the mode of generation in view. Again, the expression $a\sqrt{-1}$ shows $\sqrt{-1}$ to be a multiplier of a; but really $\sqrt{-1}$, in $a\sqrt{-1}$, is no more a factor than is $+1$ in $+a$, or -1

*It has been already remarked that the relations said to exist between lines, when we take their directions into account, cannot as yet be regarded other than hypothetical. It is, therefore, very far from our purpose to propose the substitution of the nomenclature above described for that commonly employed; but to make use of it only because, in general, it is desirable to avoid the employment of terms whose real meaning is at variance with the ideas we wish to express, even when we are concerned with an hypothesis.

in $-a$. Now we do not write $+1.a, -1.a$, but simply $+a, -a$, and the sign which precedes a itself indicates what kind of a unit this number expresses. We may then apply a similar method to imaginary quantities, writing for example $\sim a$ and χa instead of $+a\sqrt{-1}$ and $-a\sqrt{-1}$, the signs $\sim$ and χ being reciprocally positive and negative. To multiply these signs, we observe that either multiplied by itself gives $-$, and, consequently, multiplied by each other they give $+$. Moreover, a single rule, applicable to any number of factors, may be established; let every straight line, horizontal or vertical, in the signs to be multiplied, have a value 2, and every curved one a value 1; we shall have for the four signs the following values:

$$\sim=1,\ -=2,\ \chi=3,\ +=4.$$

Then take the sum of the values of all the factors and subtract as many times 4 as is necessary to make the remainder one of the numbers 1, 2, 3, 4; this remainder will be the value of the sign of the product; and so, for division, subtract the sum of the sign values of the divisor from that of the dividend, having added if necessary a multiple of 4 to the latter, and the remainder will indicate the sign of the quotient. It is to be noticed that these operations are those of multiplication and division by logarithms; this analogy will be brought more fully into view.

These new signs would abridge the notation,* and perhaps render the calculus of imaginaries more convenient, errors of sign being sometimes easily made.† We shall employ them in what follows, without implying on that account that they should be adopted. Doubtless to every innovation, even a rational one, there is an intrinsic objection; but no progress would be made if they were rejected, for the only reason that they are contrary to usage, and their trial, at least, is permissible.

9. We are now to examine the various ways in which directed lines are combined by addition and multiplication, and to determine the resulting constructions. Suppose, first, that we have to add to the positive prime line $\overline{KP}$ (Fig. 5) the line $\overline{KQ}$, also a positive

Fig. 5.

prime; the construction would not differ from that of finding the sum of the absolute lines KP, KQ; it consists in laying off the distance PR=KQ on the prolongation of KP. We then have $\overline{KP}+\overline{KQ}=\overline{KP}+\overline{PR}=\overline{KR}$. To add a negative prime line $\overline{QK}$ to another $\overline{PK}$, the construction is the same, but in the opposite direction, and we should have $\overline{PK}+\overline{QK}=\overline{PK}+\overline{RP}=\overline{RK}$. In general, if we are to add two lines of the same direction, $\overline{AB}$, $\overline{AC}$, we take in this direction, $\overline{PQ}=\overline{AB}$, $\overline{QR}=\overline{AC}$, and we have $\overline{PQ}+\overline{QR}=\overline{AB}+\overline{AC}=\overline{PR}$. If we are to add to the positive line $\overline{KP}$ the negative $\overline{QK}$, we take a distance $\overline{PS}=\overline{QK}$ in the negative direction from P, and obtain $\overline{KP}+\overline{QK}=\overline{KS}=\overline{QP}$. The same course is pursued for any other order.

Now, the principle underlying these constructions is that we regard P, the final point of $\overline{KP}$, as the initial point of the line to be added, and that we take respectively for the initial and final points of the sum, the initial point of $\overline{KP}$ and the final point of the added line. Applying this same principle to lines of other orders, we conclude that K, P, R, being any points whatever, we always have $\overline{KP}+\overline{PR}=\overline{KR}$; and as each of the lines $\overline{KP}$, $\overline{PR}$ may also be the sum of two lines, as $\overline{KM}+\overline{MP}$, $\overline{PN}+\overline{NR}$, M and N being arbitrarily chosen, we conclude that, in general, A, B; M, N, O, ..., R, S, T being any points whatever, $\overline{AB}=\overline{AM}+\overline{MN}+\overline{NO}+\overline{O}\ldots+\ldots+\ldots\overline{R}+\overline{RS}+\overline{ST}+\overline{TB}$. The points A, B, M, ... may coincide or be so situated that the lines $\overline{AM}$, $\overline{MN}$, ...

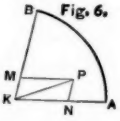
*The quantity $m \pm n\sqrt{-1}$ being denoted by $m\sim n$, or by $m\chi n$, the single sign $\sim$, or χ, replacing the four signs $+$, $\sqrt{\ }$, $-$, 1.

†For example, let it be required to multiply $-m\sqrt{-c}$ by $+n\sqrt{-cd}$. The product of the two coefficients is $-mn$; that of the two radicals is $-c\sqrt{d}$; and the final product is $+mnc\sqrt{d}$. In the new notation the two factors are $\sim m\sqrt{c}$, $\chi n\sqrt{cd}$, or $\chi m\sqrt{c}, \sim n\sqrt{cd}$, and by the rule we at once obtain $+mnc\sqrt{d}$. This advantage—if it be one—would not exist for an experienced calculator, who by a simple inspection of the factors would read the product; but not every one possesses this faculty.

coincide, intersect, etc. These circumstances are matters of indifference.*

10. Every directed line may thus be decomposed in an infinite number of ways. To decompose, for example, the line $\overline{KP}$ (Fig. 6) into two, one of an order $\overline{KA}$, the other of an order $\overline{KB}$;

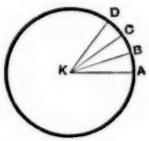
Fig. 6.



draw, through P, PN parallel to BK, and we have $\overline{KP}=\overline{KN}+\overline{NP}$. Or we might draw PM parallel to KA, and then $\overline{KP}=\overline{KM}+\overline{MP}$; but these two expressions are identical, because $\overline{KM}=\overline{NP}$ and $\overline{KN}=\overline{MP}$. As there is no other way to effect the proposed decomposition, we conclude that, if A and A′ are of the order a, B and B′ of another order b, and we have the equation $A+B=A'+B'$, then $A=A'$, $B=B'$.

11. Let us now pass to the multiplication of directed lines, and let us first construct the product $\overline{KB}\times\overline{KC}$ (Fig. 7),

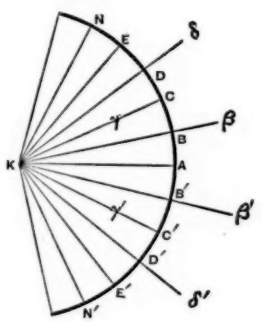
Fig. 7.



the factors being units, but not prime units. Construct the angle $\overline{CKD}=\overline{AKB}$. From what was said in No. 4, Note I, we have $\overline{KA}:\overline{KB}::\overline{KC}:\overline{KD}$, whence $\overline{KA}\times\overline{KD}=\overline{KB}\times\overline{KC}$; but $\overline{KA}=+1$, hence $\overline{KB}\times\overline{KC}=\overline{KD}$. Therefore, to construct the product of two directed radii, lay off, from the origin of arcs, the sum of the arcs corresponding to each radius, and the extremity of the arc thus laid off will determine the position of the radius of the product; this, as before, is logarithmic multiplication. It is unnecessary to show that this rule applies to any number of factors. If the factors are not units, they can be put under the form $m.\overline{KB}$, $n.\overline{KC}$, . . ., m and n being coefficients or positive prime lines, and the product would be $(mn\ldots.)\,.\,(\overline{KB}\,.\,\overline{KC}\ldots.)=(mn\ldots.)\,.\,\overline{KP}$. Now, the product of the positive prime line $(mn\ldots.)$ by the radius $\overline{KP}$ is this very line, drawn in the direction of this radius. Division is the inverse of this operation, and its explanation in detail is unnecessary.

12. By means of these rules we may operate on directed lines as on absolute ones. We now proceed to some applications of the principles already laid down, and we shall first state some immediate consequences which are of most frequent use.

Fig. 8.



§1. If AB, BC, ... , EN (Fig. 8) are equal arcs, n in number, and we make $\overline{KB}=u$, we shall have $\overline{KC}=u^2$, $\overline{KD}=u^3$, ... , $\overline{KN}=u^n$.

§2. If we lay off the arcs below KA, as AB′, B′C′, ... , E′N′, we shall have

$$\overline{KB'}=\frac{1}{u},\ \overline{KC'}=\frac{1}{u^2},\ \ldots,\ \overline{KN'}=\frac{1}{u^n}.$$

§3. Hence

$$\frac{\overline{KB}}{\overline{KB'}}=u^2,\ \frac{\overline{KC}}{\overline{KC'}}=u^4,\ \ldots,\ \frac{\overline{KN}}{\overline{KN'}}=u^{2n}.$$

§4. If, on corresponding radii, we take $K\beta=K\beta'$, $K\gamma=K\gamma'$, $K\delta=K\delta'$, ..., the distances $K\beta$, $K\gamma$, $K\delta$, . . . being arbitrary, we obtain

$$\frac{\overline{K\beta}}{\overline{K\beta'}}=u^2,\ \frac{\overline{K\gamma}}{\overline{K\gamma'}}=u^4,\ \frac{\overline{K\delta}}{\overline{K\delta'}}=u^6,\ \ldots\ldots$$

* This rule is reached by induction, and what was said in the note to No. 4, on the geometrical ratio of directed lines, is here applicable.

§5. If on the radii $\overline{KA}$, $\overline{KM}$, $\overline{KN}$ as bases, similar and equal figures be constructed, $\overline{a}$, $\overline{m}$ and $\overline{n}$ being homologous lines, then $\overline{m} = \overline{a} \times \overline{KM}$, $\overline{n} = \overline{a} \times \overline{KN}$, whence $\dfrac{\overline{m}}{\overline{KM}} = \dfrac{\overline{n}}{\overline{KN}}$, or $\overline{m} . \overline{KN} = \overline{n} . \overline{KM}$.

§6. MN being any arc of the circumference, it may at times be convenient to denote, in general, by $\overline{K.MN}$ the directed radius drawn though the extremity B of the arc AB=MN, A always being the origin of arcs. We should thus have

$$\overline{K.MN} \times \overline{K.PQ} = \overline{K.(MN+PQ)},$$

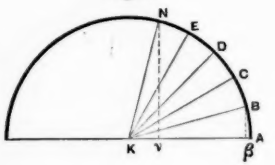
and $$\frac{\overline{K.MN}}{\overline{K.PQ}} = \overline{K(MN-PQ)}.$$

§7. If $\overline{KB}$ has the same direction as $\overline{PQ}$, we have $\overline{PQ} = PQ \times \overline{KB}$; for the absolute line PQ may be regarded as positive prime.

§8. If we have the equation $r' . \overline{PQ} = r'' . \overline{MN}$; r', r'' being unknown directed radii, and $\overline{PQ}$, $\overline{MN}$ lines of the same direction, or absolute lines, it follows that $r' = r''$, and consequently $\overline{PQ} = \overline{MN}$, or PQ=MN.

13. Now let AB, BC, ... , EN (Fig. 9) be equal arcs, n in number;

Fig. 9.



then $\overline{KN} = \overline{KB}^n$; but $\overline{KN} = \overline{K\nu} + \overline{\nu N}$, and $\overline{KB} = \overline{K\beta} + \overline{\beta B}$; hence

$$\overline{K\nu} + \overline{\nu N} = (\overline{K\beta} + \overline{\beta B})^n.$$

Let the arc AB=a, and, therefore, AN=na; then $\overline{K\beta} = \cos a$, $\overline{K\nu} = \cos na$, $\overline{\beta B} = \sim \sin a$, $\overline{\nu N} = \sim \sin na$; and the above equation becomes

$$\cos na \sim \sin na = (\cos a \sim \sin a)^n.$$

This theorem, expressed in the ordinary notation by

$$\cos na \pm \sqrt{-1} \sin na = (\cos a \pm \sqrt{-1} \sin a)^n,$$

is a fundamental one in the theory of circular functions; among its uses is the expansion of $\sin x$ and $\cos x$ into series.

Developing the binomial, equating separately the terms of the same order, and dividing by ~ 1 the equation between the medials, we have the expressions for $\cos na$ and $\sin na$; then making $na = x$, and supposing n to increase and a to diminish, x remaining constant, we have, at the limit,

$$\cos x = 1 - \frac{x^2}{2} + \frac{x^4}{2.3.4} - \frac{x^6}{2.3.4.5.6} + \ldots,$$

$$\sin x = x - \frac{x^3}{2.3} + \frac{x^5}{2.3.4.5} - \frac{x^7}{2.3.4.5.6.7} + \ldots.$$

14. From $\overline{KN} = \overline{KB}^n$ we have $\overline{KB} = \overline{KN}^{\frac{1}{n}}$, whence

$$\overline{K\beta} + \overline{\beta B} = (\overline{K\nu} + \overline{\nu N})^n = \overline{K\nu}^{\frac{1}{n}}$$

$$+ \frac{1}{n} \overline{K\nu}^{\frac{1}{n}-1} . \overline{\nu N} + \frac{\frac{1}{n}\left(\frac{1}{n}-1\right)}{2} \overline{K\nu}^{\frac{1}{n}-2} \overline{\nu N}^2$$

$$+ \frac{\frac{1}{n}\left(\frac{1}{n}-1\right)\left(\frac{1}{n}-2\right)}{2.3} \overline{K\nu}^{\frac{1}{n}-3} . \overline{\nu N}^3 + \ldots.$$

$$= \overline{K\nu}^{\frac{1}{n}} \left\{ 1 + \frac{1}{n} \frac{\overline{\nu N}}{\overline{K\nu}} + \frac{\frac{1}{n}\left(\frac{1}{n}-1\right)}{2} \cdot \left(\frac{\overline{\nu N}}{\overline{K\nu}}\right)^2 + \right.$$

$$\left. \frac{\frac{1}{n}\left(\frac{1}{n}-1\right)\left(\frac{1}{n}-2\right)}{2.3} \cdot \left(\frac{\overline{\nu N}}{\overline{K\nu}}\right)^3 + \ldots \right\}.$$

Substituting the preceding values of $\overline{K\nu}$ and $\overline{\nu N}$, and noticing that

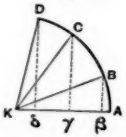
$$\frac{\overline{\nu N}}{\overline{K\nu}} = \frac{\sim \sin na}{\cos na} = \sim \tan na,$$

equating separately the terms of the same order, multiplying the equation between the medials by $\dfrac{n}{\sim 1} = \chi n$, and making the same supposition as before, there results

$$x = \tan x - \frac{\tan^3 x}{3} + \frac{\tan^5 x}{5} - \frac{\tan^7 x}{7} + \ldots.$$

15. Let (Fig. 10) the arcs $AB=a$,

Fig. 10.



$AC=b$, and let CD be taken equal to AB. Then (No. 11), $\overline{KD}=\overline{KB}\times\overline{KC}$. But

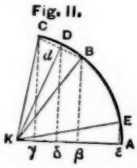
$\overline{KD}=\overline{K\delta}+\overline{\delta D}=\cos(a+b)\sim\sin(a+b)$,
$\overline{KB}=\overline{K\beta}+\overline{\beta B}=\cos a\sim\sin a$,
$\overline{KC}=\overline{K\gamma}+\overline{\gamma C}=\cos b\sim\sin b$; hence
$\cos(a+b)\sim\sin(a+b)$
$=(\cos a\sim\sin a)(\cos b\sim\sin b)$.

Expanding the second member and equating the orders separately, we have

$$\cos(a+b)=\cos a\cos b-\sin a\sin b,$$
$$\sin(a+b)=\cos a\sin b+\sin a\cos b.$$

16. Let $AC=a$, $AB=b$ (Fig. 11); draw

Fig. 11.



the chord BC, and the radius KD, bisecting the angle BKC. Make $AE=BD=\frac{a-b}{2}$, and draw KE and $E\varepsilon$. Then

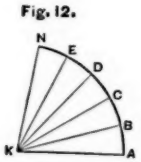
$\overline{K\gamma}+\overline{\gamma C}-(\overline{K\beta}+\overline{\beta B})=\cos a\sim\sin a-(\cos b\sim\sin b)=\cos a-\cos b\sim(\sin a-\sin b)=\overline{KC}-\overline{KB}=\overline{KC}+\overline{BK}=\overline{BC}=\overline{2dC}$
$=$[No. 12, § 5] $2\,\overline{\varepsilon E}\times\overline{KD}=$
$\sim 2\sin\frac{a-b}{2}\left(\cos\frac{a+b}{2}\sim\sin\frac{a+b}{2}\right)$;

whence

$$\cos a-\cos b=-2\sin\frac{a-b}{2}.\sin\frac{a+b}{2},$$
$$\sin a-\sin b=+2\sin\frac{a-b}{2}.\cos\frac{a+b}{2}.$$

17. Divide the arc AN (Fig. 12) into n equal parts. The radii $\overline{KA}$, $\overline{KB}$, $\overline{KC}$, . . . , $\overline{KN}$ are in geometrical progression, but the corresponding arcs are in arithmetical progression, and may therefore be taken for the logarithms of these radii. Put $m\,AN=\log\overline{KN}$, m being the arbitrary modulus; we then have $\log\overline{KN}=m.AN=mn\,AB$. Making n infinity, so

Fig. 12.



that the arc AB may be regarded as a right line perpendicular to KA, we have $\overline{AB}=\sim AB$, or $\overline{AB}=\chi AB$, and $\log\overline{KN}=\chi\,mn.AB$, or $\log\overline{KN}=mn.\overline{AB}$; for since m is arbitrary, we may substitute m in place of χm. Now $\overline{AB}=\overline{AK}+\overline{KB}$
$=-1+\overline{KN}^{\frac{1}{n}}$; hence

$\log\overline{KN}=mn\left(-1+\overline{KN}^{\frac{1}{n}}\right)$, and, putting $KN=1+x$, $\log(1+x)=mn$

$$\left\{-1+1+\frac{1}{n}x+\frac{\frac{1}{n}\left(\frac{1}{n}-1\right)}{2}x^2+\frac{\frac{1}{n}\left(\frac{1}{n}-1\right)\left(\frac{1}{n}-2\right)}{2\,.\,3}x^3+\ldots\right\}$$
$$=m\left(x-\frac{x^2}{2}+\frac{x^3}{3}-\frac{x^4}{4}+\ldots\right).$$

18. Let us now divide the two equal arcs AN, AN′ (Fig. 13) into n equal parts; draw the tangent mm' and the secants Kb, Kc, . . . , Kn; Kb', Kc', ... , Kn'.

We have seen (No. 12, § 4) that, when $\overline{KB}=u$,

$$\frac{\overline{Kb}}{\overline{Kb'}}=u^2,\ \frac{\overline{Kc}}{\overline{Kc'}}=u^4,\ \ldots,\ \frac{\overline{Kn}}{\overline{Kn'}}=u^{2n}.$$

Thus, as before, the quantities

$$\frac{\overline{KA}}{\overline{KA'}},\ \frac{\overline{Kb}}{\overline{Kb'}},\ \frac{\overline{Kc}}{\overline{Kc'}},\ \ldots,\ \frac{\overline{Kn}}{\overline{Kn'}}$$

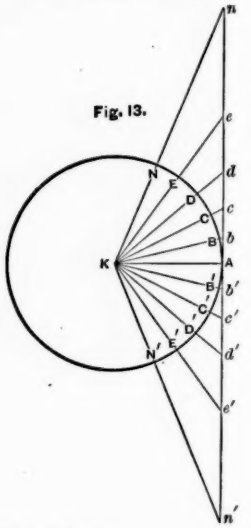
are in geometrical progression, and the corresponding arcs may be taken for their logarithms, as for example

$$AN=m\log\frac{\overline{Kn}}{\overline{Kn'}}.$$

Let $AN=x$, and consequently

$$\overline{Kn}=\overline{KA}+\overline{An}=1\sim\tan x,$$
$$\overline{Kn'}=\overline{KA}+\overline{An'}=1\chi\tan x;$$

Fig. 13.



then we have at once

$$x=m\log\frac{1\sim\tan x}{1\chi\tan x}.$$

But we have seen the arc

$$x=\tan x-\frac{\tan^3 x}{3}+\frac{\tan^5 x}{5}-\ldots;$$

hence

$$m\log\frac{1\sim\tan x}{1\chi\tan x}=\tan x-\frac{\tan^3 x}{3}+\frac{\tan^5 x}{5}-\ldots$$

Putting $\sim\tan x=z$, this becomes

$$m\log\left(\frac{1+z}{1-z}\right)=\sim\left(z+\frac{z^3}{3}+\frac{z^5}{5}+\frac{z^7}{7}+\ldots\right),$$

or, dividing both members by ~ 1, and noticing that, m being arbitrary, m may be substituted for $\frac{m}{\sim 1}$,

$$m\log\left(\frac{1+z}{1-z}\right)=z+\frac{z^3}{3}+\frac{z^5}{5}+\frac{z^7}{7}+\ldots.$$

19. Resuming the equation

$$x=m\log\frac{1\sim\tan x}{1\chi\tan x},$$

and making $\sim\tan x=z$ as before, let us substitute $\frac{m}{\sim 2}$ for m, or, what is the same thing, make $x=\sim 2x$ in the first member. These changes give

$$\sim 2x=m\log\frac{1+z}{1-z}=\log(1+2z+2z^3+2z^5+\ldots),$$

and

$$\sim 2nx=m\log(1+2z+2z^3+2z^5+\ldots)^n.$$

Now make $\sim 2nx=y$, and suppose n to increase and x to decrease without limit, y remaining constant; $z=\sim\tan x$ will then be infinitely small; hence, in the second member of the development the terms following $2z$ may be omitted, under which supposition the equation reduces to $y=m\log(1+2z)^n$.

The same supposition gives $z=\sim\tan x=\sim x$, $2nz=\sim 2nx=y$, and, therefore, $2z=\frac{y}{n}$. We may then write

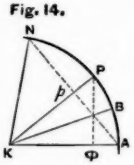
$$y=m\log\left(1+\frac{y}{n}\right)^n$$
$$=m\log\left(1+n.\frac{y}{n}+\frac{n(n-1)}{1.2}.\frac{y^2}{n^2}+\frac{n(n-1)(n-2)}{1.2.3}.\frac{y^3}{n^3}+\ldots\right),$$

and, finally, since $n=\infty$,

$$y=m\log\left(1+y+\frac{y^2}{2}+\frac{y^3}{1.2.3}+\frac{y^4}{1.2.3.4}\cdots\right).$$

20. Suppose the arc AN (Fig. 14) to

Fig. 14.



be divided into an infinite number n of equal parts, of which AB is the first. Take $\overline{AP}=\frac{1}{2}\overline{AN}$, and draw AN, KP and P$\varphi$. We have

$$\overline{AB}=\overline{AK}+\overline{KB}=-1+\overline{KN}^{\frac{1}{n}}$$
$$=-1+(\overline{KA}+\overline{AN})^{\frac{1}{n}}=-1+(1+\overline{AN})^{\frac{1}{n}}.$$
$$=-1+1+\frac{1}{n}.\overline{AN}+\frac{\frac{1}{n}\left(\frac{1}{n}-1\right)}{2}.\overline{AN}^2+\frac{\frac{1}{n}\left(\frac{1}{n}-1\right)\left(\frac{1}{n}-2\right)}{2.3}.\overline{AN}^3+\ldots$$
$$=\frac{1}{n}\left(\overline{AN}-\frac{\overline{AN}^2}{2}+\frac{\overline{AN}^3}{3}-\frac{\overline{AN}^4}{4}+\ldots\right)$$

and $$n\,.\,\overline{AB} = \overline{AN} - \frac{\overline{AN}^2}{2} + \frac{\overline{AN}^3}{3} - \frac{\overline{AN}^4}{4} + \ldots\ldots;$$

whence $n\,.\,\overline{AB} = \sim n\,.\,AB = \sim$ arc AN, and

$$\overline{AN} = 2\rho\overline{N} = [\text{No. 12, §5}]\ 2\varphi P \times \overline{KP} = \sim 2\sin\frac{AN}{2}\cdot\left(\cos\frac{AN}{2} \sim \sin\frac{AN}{2}\right),$$

or, putting the arc $\frac{AN}{2} = a$, $\overline{AN} = -2\sin a$ $(\cos a \sim \sin a)$, and therefore

$$\overline{AN}^2 = -(2\sin a)^2(\cos 2a \sim \sin 2a),$$
$$\overline{AN}^3 = \chi(2\sin a)^3(\cos 3a \sim \sin 3a),$$
$$\overline{AN}^4 = +(2\sin a)^4(\cos 4a \sim \sin 4a),$$
$$\overline{AN}^5 = \sim \ldots\ldots\ldots$$

Substituting these values in the above series, retaining the medial terms only, since this series is equal to $n.\overline{AB} = \backsim 2a$, and dividing by $\backsim 1$, we have

$$2a = 2\sin a.\cos a + \frac{(2\sin a)^2\sin 2a}{2} - \frac{(2\sin a)^3\cos 3a}{3} - \frac{(2\sin a)^4\sin 4a}{4} + \ldots\ldots$$

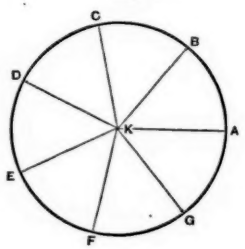
Since the sum of the prime terms must be zero, we have

$$0 = -2\sin a.\sin a + \frac{(2\sin a)^2\cos 2a}{2} + \frac{(2\sin a)^3\sin 3a}{3} - \frac{(2\sin a)^4\cos 4a}{4} - \ldots,$$

an equation which may be divided by $2\sin a$.

21. Divide the circumference (Fig. 15)

Fig. 15.



into n equal parts, AB, BC, . . . GA; n is now a finite quantity. We propose to find the sum S of the mth powers of the radii $\overline{KA}$, $\overline{KB}$, ... $\overline{KG}$.

Let $\overline{KB} = u$, whence $\overline{KC} = u^2$, $\overline{KD} = u^3$, . . . , $\overline{KG} = u^{n-1}$, $\overline{KA} = u^n = 1$; then

$$S = 1 + u^m + u^{2m} + \ldots + u^{(n-1)m},$$

and

$$u^m S = u^m + u^{2m} + \ldots + u^{(n-1)m} + u^{nm};$$

but $u^{nm} = (u^n)^m = 1^m = 1$;

hence $u^m S = S$, and $(u^m - 1)S = o$.

If $u^m = 1$, this is an identical equation, without meaning; but, in this case, $u^{2m} = 1$, $u^{3m} = 1$, . . . ; hence $S = n$. In all other cases $S = o$.

If we denote by P', P'', P''', ... , $P^{(n)}$ the sum of the first, second, ... , nth powers of given quantities, and by Π', Π'', Π''', ... , $\Pi^{(n)}$ the sum of the products of the same quantities taken one and one, two and two, ... , n and n, it is well known that

$$n\Pi^{(n)} = P'\Pi^{(n-1)} - P''\Pi^{(n-2)} + P'''\Pi^{(n-3)} - \ldots \pm P^{(n-3)}\Pi''' \mp P^{(n-2)}\Pi'' \pm P^{(n-1)}\Pi' \mp P^{(n)},$$

the upper and lower signs corresponding to the cases in which n is even or odd, respectively. The demonstration of this theorem may be reduced to a simple algebraic transformation. If we apply it to the radii $\overline{KA}$, $\overline{KB}$, ... , $\overline{KG}$, which are n in number, we shall obtain $P' = o$, $P'' = o$, $P''' = o$, ... , $P^{(n-1)} = o$ $P^{(n)} = n$; whence

$$\Pi' = o,\ \Pi'' = o,\ \ldots\ldots,\ \Pi^{(n-1)} = o,\ n\Pi^{(n)} = \mp n,$$
and $$\Pi^{(n)} = \mp 1 = -(-1)^n.$$

These properties may also be derived from the equation $x^n - 1 = o$, whose roots are $\overline{KA}$, $\overline{KB}$, ... , $\overline{KG}$.

THE contractors of the St. Gothard Tunnel have applied to the Federal Tribunal to prolong, by seven hundred days, the time originally fixed for the completion of the undertaking. This request is declared to be merely their answer to the company's claim for the enforcement of the penalty of delay (5000 francs a day), and does not signify that the undertaking will not be completed next year. They contend that if the company had done their duty the tunnel would have been finished seven hundred days sooner than is now possible. It is generally well known that the company greatly delayed the contractors.

THE FLOW OF COMPRESSED AIR THROUGH LONG PIPES.

Experiments at St. Gothard Tunnel, par E. STOCKALPER, Ingenieur Chef de Service.

Translated from Revue Universelle des Mines.

THE differences which exist between the co-efficients in the different works or tables which treat of the flow of compressed air, or permanent gases in long pipes, renders completely uncertain any calculation regarding the loss of charge for a given case.

The greater part of these co-efficients do not coincide with the observations which we have been called upon to make for the delivery of air at the tunnel of St. Gothard. The cause may be referred to the fact, that the experiments which have served to establish these co-efficients have generally been made upon short pipes with low pressures and small volumes of air; that is to say, under conditions not corresponding to the transmission of motive power to long distance.

In order to study the conditions of flow of compressed air, the different factors to be taken into account, are:

1st. The lengths, diameter and nature of the conduit.
2d. The velocity of flow, or the volume of compressed air passing her section through a given section.
3d. The pressures of air at different points along the conduit.
4th. The temperatures in the conduit.

1st. The conduit at St. Gothard tunnel, upon which experiments were made, was composed of—

(*a*). Pipes of cast and of wrought iron of $0.^{m}2$ diameter, 4,600 meters long, and with flange and bolt joints enclosing rubber rings.

(*b*). Wrought iron pipes of $0.^{m}15$ diameter, 522 meters long, with same joints as above.

(*c*). Wrought iron tubes of $0.^{m}10$ diameter and joints as before.

Experiments were not made upon the smaller conduit because of the numerous branchings for delivery upon this portion.

The pipe being practically tight, the losses of air may be neglected in comparison to the amount of air delivered. The bends also need not be taken into account in relation to the total length.

2d. Velocity or volume delivered per second. This was measured by the compressors, which were pumps of the Colladon variety. Their capacity was determined by previous experiments upon a reservoir of 166.50 cubic meters capacity.

3d. The pressures along the conduit were measured by Bourdon gauges measuring to one-twentieth of an atmosphere. For each gauge a correction curve was established by comparing with a standard manometer, a work performed by Prof. D. Colladon, consulting engineer.

4th. The temperatures were taken by thermometers with bulbs inside the conduit, but with their tubes exposed. For these also a correction co-efficient was necessary, as the bulbs were subjected to pressure of the air in the pipe.

In conducting the observations the pressure gauges were applied at eight different points along 5,100 meters of pipe, the furthermost one being at some distance from the branches. Readings were taken every ten minutes.

In order to simplify this account we will regard only the gauges at the principal points—at the points where the diameter changes and at the compressors.

The conditions of different permanent regimens was sought for—that is to say, the relations between certain amounts of air delivered at the terminus, the air furnished by the compressor, and the corresponding constant pressures along the pipe.

These different conditions have been obtained by regulating the work of the compressors or by controlling the delivery at the end of the pipe by aid of regulator cocks.

It is to be regretted that the temperature observations were not made simultaneously with the pressure readings. The thermometers were read at a later period, but it was evident that the re-

sults of calculations are not influenced by this fact.

The analogy between the flow of water and that of permanent gases, and especially the information afforded by the results of these experiments render it desirable to review here the formulæ for the flow of water in pipes.

The most satisfactory formulæ, whether regarded for their simplicity or their practical utility, are those of Darcy.

A resumé of his formulæ and tables is herewith given:

The tables are based on the assumption that the resistance of friction is given with sufficient exactness by the monomial formula

$$(1) \qquad \frac{DJ}{2} = b_1 u^2$$

in which u is the velocity in meters per second. D=diameter in meters and J=loss of charge per running meter.

The values of b_1 for wrought or cast iron pipes of diameters, between $0.^m0122$ and $0.^m50$, are expressed by the formula

$$b_1 = 0.000507 + \frac{0.00001294}{D}$$

From the formula 1 we get

$$D = \frac{2b_1 u^2}{J}, \qquad J = \frac{2b_1 u^2}{D},$$

$$u = \sqrt{\frac{JD}{2b_1}}$$

If Q= the volume delivered per second, then $Q = \frac{\pi D^2}{4} u$ or $u = 1.273 \frac{Q}{d^2}$

also, $Q = \frac{\pi}{4} \sqrt{\frac{JD^5}{2b_1}}$ $\qquad D = \sqrt[5]{\frac{32Q^2 b_1}{\pi^2 J}} =$

$$= \sqrt[5]{3.2423 \frac{b_1 Q^2}{J}},$$

$$J = 3.2423 \frac{b_1}{D^5} Q^2$$

Representing the value of the co-efficient of Q^2 by a, this last formula becomes $J = a Q^2$

whence also

$$a = \frac{J}{Q^2} \text{ and } Q = \sqrt{\frac{J}{a}}$$

These formulæ are applicable to either drawn or cast iron pipes.

The following table contains the values of a for different values of D, deduced from Darcy's experiments:

Diameters D.	Values of a.	Diameters D.	Values of a.	Diameters D.	Values of a.
0,01	58395000,	0,18	9,918	0,39	0,194055
0,02	1169250,	0,19	7,5295	0,40	0,17067
0,027	222800,	0,20	5,7855	0,41	0,15056
0,03	125155,	0,21	4,50925	0,42	0,133225
0,04	26280,5	0,216	3,90305	0,43	0,118435
0,05	7937,	0,22	3,5546	0,44	0,10538
0,054	5267,5	0,23	2,8361	0,45	0,094005
0,06	3010,45	0,24	2,2805	0,46	0,08422
0,07	1333,05	0,25	1,8526	0,47	0,075495
0,08	660,95	0,26	1,51725	0,48	0,067825
0,081	619,3	0,27	1,2518	0,49	0,06118
0,09	356,905	0,28	1,0418	0,50	0,055195
0,10	206,21	0,29	0,8710	0,55	0,034114
0,108	138,135	0,30	0,73385	0,60	0,0220155
0,11	125,625	0,31	0,6206	0,65	0,0146985
0,12	80,005	0,32	0,52855	0,70	0,010128
0,13	52,92	0,325	0,488235	0,75	0,0071595
0,135	43,529	0,33	0,45235	0,80	0,005175
0,14	36,111	0,34	0,388915	0,85	0,00381445
0,15	25,3195	0,35	0,33521	0,90	0,00286075
0,16	18,1505	0,36	0,29063	0,95	0,00173075
0,162	17,0285	0,37	0,252955	1,00	0,00168275
0,17	13,313	0,38	0,221375		

For pipes in actual use it is necessary to double the values of a found in the table.

The fundamental formulæ for the flow of permanent gases are derived from the differential equation afforded by the mechanical theory of heat.

Under the hypothesis that during the

flow of the compressed air, heat is neither added nor abstracted, the following formulæ are deduced:

$$3\ \begin{cases} \dfrac{u_2^2}{2g} = \dfrac{C}{A}(T_1 - T_2) \\ \dfrac{T_2}{T_1} = \left(\dfrac{p_2}{p_1}\right)^{\frac{k-1}{k}} \end{cases}$$

In which

u_2=final velocity in meters for second.
g=9.81.
C=0.2377 specific heat of air.
$\frac{1}{A}$=436 mech. equivalent of heat.
$T_2 = 273 + t^0_2$ absolute final temperature.
$T_1 = 273 + t^0_1$ absolute initial temperature.
k=1 41.
p_1=pressure in kilos. per sq. meter beginning of conduit.
p_2=pressure at extremity of conduit.

The hypothesis is strictly correct only for a conduit which will not conduct heat.

The above formulæ indicate that the temperature of the air in the pipe is lowered in the same proportion as the air expands; or, in other terms, the heat diminishes in the same proportion as the pressure in the conduit.

Under the hypothesis that the gas is maintained at a constant temperature, we have the equation

$$(4)\quad \frac{u_2^2}{2g} = \text{R.T. nat.log}\frac{p_1}{p_2}$$

in which T is the absolute temperature and R is the constant of Mariotte and Gay-Lussac, which for air is 29,269.

This hypothesis assumes that heat is added, during the flow through the pipe, in quantity to supply the loss due to expansion.

Evidently, neither of these hypotheses is exactly realized in the practical application, but it is proper to determine by trial which best represents the real conditions, and so determine which is best to accept as a basis for calculation. For a practical beginning of the problem, the following thermometric experiments were made in the conduit. Thermometers were inserted along the conduit at different points. Upon each a series of observations were made at different days, the velocity varying from 4 to 12 meters and the pressure from 3 to 6 atmospheres. At the same time the temperature of the air outside the conduit was taken at each point, this being the temperature of the tunnel and constant for each point.

The observations made show that notwithstanding the variation of velocity and pressure, the temperature of the compressed air remained practically the same for each point, varying not more than half a degree; and that from point to point advancing into the tunnel it increased with the temperature of the tunnel.

Omitting the observations near the entrance where the temperature is variable, and beginning at a point 800 meters within the tunnel, it was found that the temperature of the compressed air was about three degrees below the temperature of the air of the tunnel at each point.

It was concluded that owing to the feeble calorific capacity of air, and the high conducting qualities of metal pipes, that compressed air will take, in long conduits, practically the same temperature as the surrounding medium.

In general, therefore, the medium traversed by the conduit being constant, formula 4, established under the last hypothesis, is best adapted for general application.

To facilitate calculations this may be somewhat modified.

We may write

$$\text{Nat. log.}\frac{p_1}{p_2} = \text{nat. log.}\frac{p_2 + p_1 - p_2}{p_2} = \text{nat. log.}\left(1 + \frac{p_1 - p_2}{p_2}\right).$$

Remembering that

$$\text{nat. log.}\,(1+\chi) = \chi - \frac{\chi^2}{2} \ldots$$

we shall have, taking only the first term:

$$\text{nat. log.}\frac{p_1}{p_2} = \frac{p_1 - p_2}{p_2}$$

consequently

$$(5)\quad \frac{u_2^2}{2g} = \text{RT}\frac{p_1 - p_2}{p_2}\ *$$

Let now the density of the air or its weight per cubic meter be introduced.

* This equation is the one used in calculations. By writing p_1 for p_2 in the denominator, and introducing a coefficient of friction z, and admitting that friction is proportional to the square of the velocity, also directly as the length and inversely as the diameter of the pipe, we have:

$$\frac{u^2}{2g} = \text{RT.} = \frac{zL}{D} \cdot \frac{p_1 - p_2}{p_1}$$

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We know that for permanent gases

$$\frac{p\,v}{T} = R, \text{ a constant}$$

v=the volume of a unit weight.
δ=density; wt. per meter cube,

then $$v = \frac{1}{\delta}$$

and $$\frac{p}{\delta T} = R$$

consequently $$\frac{RT}{p_2} = \frac{1}{\delta_2}$$

Substituting in eq. (5) it becomes

$$\frac{u_2^2}{2g} = \frac{p_1 - p_2}{\delta_2}$$

In this equation if we use the mean values of velocity, density and temperature by taking

$$u = \frac{u_1 + u_2}{2}$$

$$\delta = \frac{\delta_1 + \delta_2}{2}$$

and $$T = \frac{T_1 + T_2}{2}$$

we shall have

$$(6) \qquad \frac{u_2}{2g} = \frac{p_1 - p_2}{\delta}$$

No account has yet been taken of the loss due to friction. The diminution of pressure serves not only to increase the velocity—it should also aid in diminishing friction. In the case of water, Darcy's experiments have shown that it is sufficiently exact to assume that the frictional resistance is simply proportional to the square of the velocity, instead of the more complex value of $au + bu^2$. We may readily admit the same hypothesis for air, with less liability of error where the resistance to friction is less and the velocities in general are greater.

If we express this resistance by zu^2 the formula (6) becomes

$$\frac{u^2}{2g} + zu^2 = \frac{p_1 - p_2}{\delta}$$

$$\left(\frac{1}{2g} + z\right) u^2 = \frac{p_1 - p_2}{\delta}$$

in which the factor in parenthesis is a co-efficient constant for each pipe and for each diameter D, a co-efficient which, from analogy with resistances of water, we may place equal to

$$\frac{2b_1}{D} l$$

in which l is the length of the conduit.

We shall then have

$$\frac{2b_1}{D} l u^2 = \frac{p_1 - p_2}{\delta}$$

Calling J the difference of pressure $p_1 - p_2$ per running meter, we shall have

$$\frac{2b_1}{D} u^2 = \frac{J}{\delta}$$

Using a function of the volume Q in place of the velocity v

$$Q = \frac{\pi D^2}{4} u$$

$$u^2 = \frac{16\ Q^2}{\pi^2\ D_4}$$

By substitution it becomes

$$3.2423 \frac{b_1 Q^2}{D^5} = \frac{J}{\delta}$$

in which Q is the mean volume and

$$= \frac{Q_1 + Q_2}{2}.$$

Taking as Darcy does

$$\frac{3.2432\, b}{D^5} = a_1,$$

we shall have the formula under its final form.

$$(7) \quad \begin{cases} J = a_1 Q^2 \delta \\ a_1 = \dfrac{J}{Q_2 \delta} \\ Q = \sqrt{\dfrac{J}{a_1 \delta}} \end{cases}$$

in which the density

$$\delta = \frac{p}{RT}$$

This formula (7) is quite analogous to Darcy's formula given above for the flow of water. For the density of water being constant whatever the pressure, the value of δ is unity; but if we take $\delta = 1000$ the previous formula would have given

$$J = \frac{a}{1000} Q^2 \delta$$

the value of the numerical co-efficient of a.

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The complete analogy between the formulæ suggests, that taking the influence of the density into account $\frac{a}{1000}$ be substituted for a, the latter being the co-efficient for water employed in Darcy's tables.

$$a_1=\frac{a}{1000}$$

is employed in the following calculations.

(Experiments made Dec. 17th, 1878, at St. Gothard Tunnel, north side).

The quantity of air during the first set of trials, was

$v_0=0.936$ cubic meters per second,

measured at 0°C, and average atmospheric pressure at Paris.

1st. For the pipe $0.^m20'$ diameter and 4,600 meters length, the pressure at the entrance

$p_1=5.66$ atmospheres
at 4,600 meters $p_2=5.24$ "

The loss of pressure was 0.36 atmospheres.

The mean pressure was 5.42 atmospheres.

The mean temperature, being that at the middle point, was $t=21°$; hence $T=294°$.

The volume delivered per second under these conditions should be

$$Q=\frac{v_0}{p}(1+0.00366\times t)=0.185$$ cubic meters.

For water, Darcy's table gives
when $D=0.20$ and $a=5.785$,
the loss of pressure per running meter,

$$J=aQ^2=5.785\times\overline{0.185}^2=0.198;$$

and the loss for length of 4600 meters $p_1-p_2=0.198\times4600=910$ meters, head of water.

For air the loss would be

$$p_1-p_2=\frac{910\times\delta}{1000} \text{ in which } \delta=\frac{p}{RT}$$

$$\text{kilos. per sq. meter}=\frac{5.42\text{ atm.}\times10334}{2.93\times294}=6.^k500.$$

This substituted above gives:
Loss of charge in head of water

$$p_1-p_2=\frac{910\times6.500}{1000}=5.^m91$$

$$\text{in atmospheres}=\frac{5.91}{10.334}=0.57 \text{ atmospheres}$$

calculated loss $=0.57$ atmospheres
observed loss $=0.36$ "
Difference 0.21 "

Loss of pressure on second section of the conduit, diameter of $0.^m15$ and length 522 meters,

$p_1=5.24$ atm.; $p_2=5.00$,
loss observed $=0.24$ atmospheres.

Mean temperature

$t=26.5$, $T=299.5$ $p=5.12$

$$Q=\frac{0.936\ (1+0.00366\times26.5)}{5.12}=0.20$$

For water
when $D=0.15$ $a=25.32$
$J=aQ^2=1.01$
per running meter. For 522 meters = 527.22 meters, head of water.

For air this becomes

$$p_1-p_2=\frac{527.22\times\delta}{1000}$$

but $$\delta=\frac{5.12\times10334}{29.3\times299.5}=6.^k03$$

hence $$p_1-p_2=\frac{527.22\times6.03}{1000}=3.^m18$$

of water

$$=\frac{3.18}{10.334}=0.30 \text{ atmospheres.}$$

The loss observed was 0.24
Difference = 0.06 atmospheres.

SECOND SET OF EXPERIMENTS.

During this series, the volume of air, at standard temperature and pressure, was:

$v_0=0.623$ cubic meters per second.

Loss of pressure in the larger pipe was, by observation:

$p_1=4.35$
$p_2=4.13$
$p_1-p_2=0.22$ atmospheres.

mean pressure $=4.285$
mean temperature, $t=21°$, $T=294$
hence, $Q=0.156$ cub. meters.

For water this would be:

$D=0.20$, $a=5{,}785$,

and $J=aQ^2=0.1408$ per running meter; and for 4,600 meters:

$p_1-p_2=647.68$ meters of head.

For air this becomes:

$$p_1 - p_2 = \frac{647.68 \times \delta}{1000}$$

but $\delta = 5^k.14$

hence $p_1 - p_2 = 3.329$ meters head of water.

$$= \frac{3.329}{10.334} = 0.32 \text{ atmospheres.}$$

Loss of pressure
observed = 0.22 "

Difference = 0.10 "

Loss of pressure in second section of pipe. Diameter, $0^m.15$; length, 522 meters.

$p_1 = 4.13$
$p_2 = 4.06$
loss = 0.07 atmospheres.

mean pressure = 4.095
$t = 26.5$, T = 299.5

whence Q is found to be 0.166 cu. meters.

For water:

when D = 0.15 $a = 25.32$

$J = a\,Q^2 = 0.6977$ per running meter.

For 522 meters = 364.20 meters head of water.

For air:

$$p_1 - p_2 = \frac{364.20 \times \delta}{1000}$$

$$\delta = \frac{4.095 + 10334}{29.3 \times 299.5} = 4.82$$

hence $p_1 - p_2 = 1.75$ meters head of water.

$$= \frac{1.75}{10.334} = 0.17 \text{ atmospheres.}$$

Loss observed, = 0.07
Difference, = 0.10 atmospheres.

THIRD SET OF EXPERIMENTS.

During this series the volume of air, measured under standard conditions of temperature and pressure was $v_0 = 0.520$ cub. meters per second.

In the larger pipe, $p_1 = 3.84$
$p_2 = 3.65$
loss, $p_1 - p_2 = 0.19$ atmospheres.

Mean pressure = 3.745 atm.
$t = 21°$, T = 294
Q = 0.149 cub. meters.

For water:

when D = 0.20, a 5.785
$J = a\,Q^2 = 0.127$

and for 4600 meters = 584.2 meters head.

For air:

$$p_1 - p_2 = \frac{584.20 - \delta}{1000}$$

but $\delta = 4^k.49$

hence $p_1 - p_2 = 2.62$ meters head of water.

$$= \frac{2.62}{10.334} = 0.25 \text{ atmospheres.}$$

Loss observed, = 0.19
Difference, = 0.06 atmospheres

Loss of pressure in second section of pipe:

$p_1 = 3.65$ atm.
$p_2 = 3.545$ "
loss, $p_1 - p_2 = 0.105$ "

Mean pressure = 3,597
$t = 26.5°$ T = 299.5
Q = 0.158 cubic meters.

For water this would be:

when D = 0.15 and $a = 25.52$
$J = a\,Q^2 = 0.632$

for a length of 522 meters

$$p_1 - p_2 = 329.90.$$

For air this becomes

$$p_1 - p_2 = \frac{329.90 \times \delta}{1000}$$

$$\delta = 4.^k23$$

hence $p_1 - p_2 = 1.395$ meters of water.

$$= \frac{1.395}{10.334} = 0.135 \text{ atmospheres}$$

loss observed = 0.105
difference = 0.03 atmospheres.

In the application of these principles there may be considered as given the quantity Q or the velocity u, the pressure p_1 and the temperature t_0 as data for calculating the approximate loss of pressure. The result for given cases would be arrived at by successive approximations.

To compare the above results with those obtained by using the formulæ generally employed to calculate the loss of pressure during the flow of gases, we will review these formulæ, preserving the above notation.

The best known formula is

$$p_1 - p_2 = \varphi \cdot \frac{l}{D} \cdot \frac{p}{RT} \cdot \frac{u^2}{2g}$$

in which

$$\frac{p}{RT} = \delta$$

and consequently

$$p_1 - p_2 = \varphi \cdot \frac{l}{D} \cdot \delta \cdot \frac{u^2}{2g}$$

in which, according to Girard, D'Aubuisson or Pecquer, φ should be taken

$$. \quad = 0.024,$$

and according to Weisbach,

$$= \frac{0.12}{\sqrt{u}}.$$

Morin's formula is

$$p_1 - p_2 = \frac{u^2}{2g} \delta \left(1 \pm 0.0252 \frac{l}{D}\right).$$

Arson has prepared tables from the formula

$$p_1 - p_2 = \frac{4l}{D} \delta (au + bu^2)$$

in which for the pipes above considered

$D = 0.^m20$, $a = 0.00033$, $b = 0{,}000395$
$D = 0.^m15$, $a = 0.00044$, $b = 0{,}000430$

The above formulæ express the loss of pressure in kilogrammes per sq. meter, which, for the sake of comparison with the results above obtained, will be reduced to atmospheres by dividing by 10334.

Applying these different formulæ the results, as exhibited in the following table, are obtained :

	Diameter.	Length.	Cor. vol. v_0.	Mean pressure.	Mean temperature.	Wt. per cubic meter.	Q.	Mean velocity.	Loss of pressure.				
									Observed.	Calculated.			
										$J = aQ^2/b$.	d'Aubuisson, etc.	Morin.	Arson.	Weisbach.
	M.	M.	M³.	Atm		Kil.	M³.	M.						
First Series.....	0,20	4600	0,936	5,42	21°	6,500	0,185	5,89	0,36	0,57	0,61	0,64	0,90	1,25
	0,15	522	0,936	5,12	26,5	6,030	0,200	11,32	0,24	0,30	0,31	0,34	0,48	0,46
Second series.....	0,20	4600	0,623	4,285	21	5,140	0,156	4,968	0,22	0,32	0,345	0,30	0,52	0,76
	0,15	522	0,623	4,095	26,5	4,820	0,166	9,394	0,07	0,17	0,175	0,15	0,27	0,29
Third series..... ..	0,20	4600	0,520	3,745	21	4,490	0,149	4,747	0,19	0.25	0,27	0,29	0,41	0,63
	0,15	522	0,520	3,597	26,5	4,230	0,158	8,942	0,105	0.135	0,14	0.15	0,22	0,23

From an inspection of the table, the following conclusions are readily drawn :

1st. The losses of pressure calculated by the formulæ, are sensibly greater than the observed amounts.

2d. That the co-efficient of Morin is probably derived from the experiments of d'Aubuisson and Girard.

3d. That Weisbach gives too high values, especially for low velocities.

4th. That although the co-efficients of Arson have been derived from the most precise experiments, they nevertheless give too small values for loss of pressure under the conditions of the above experiments.

This fact is probably due to the low pressures at which his experiments were conducted ; only $0.^m14$ of water at the maximum, and for the purpose of distributing illuminating gas.

5th. That our formula employing the co-efficients of Darcy, gives results more nearly according with observation than any of the others.

It is to be regretted that we have not the results of the experiments made in 1852 by Prof. Colladon, to compare with the above list.

In an address delivered in June, 1857—an address which led the Chamber to decide upon tunneling Mont-Cenis, Gen. Menabrea said :

"The honor of having suggested this rational idea belongs to Prof. Colladon, of Geneva. He proposes to drive the drilling machines, not by cords and pulleys, but by compressed air."

He added : "The experiments of M. Colladon have proved that air, when conducted through pipes, meets with much less resistance than some writers

have supposed; this resistance being the obstacle which has led to serious doubt whether air could be conveyed long distances and preserve its elastic force."

We find in a publication of M. Hudry-Menos in 1871, entitled "Le Tunnel des Alpes," an approximate statement of the result attained by M. Colladon:

"The transmission of compressed air to great distances was the fine achievement of the great enterprise. . . . . M. Colladon, fortified by numerous experiments in 1852, upon a pipe 0.^{m}25 in diameter and 700 meters long, announced in a memoir accompanying his demand for a patent, that tbe co-efficients of resistance, adopted up to that time for the movement of gases in smooth conduits, was too high and should be reduced to about one-half."

We may state here that our experiments confirm the conclusions announced in 1852 by M. Colladon, in the sense that the losses of pressure which we have observed are about two-thirds of the amounts deduced from the formulæ of Girard and d'Aubuisson, and about one-half those of Arson.

In this article we have shown theoretically that the loss of pressure in air conduits may be written like that for water conduits under the form,

$$J = a_1 Q^2 \delta,$$

and our experiments justify the conclusion that for practical purposes the co-efficient a_1 is the same for air as for water, or in other words, to calculate the loss of charge in an air conduit, it will suffice to estimate the loss as though it were water moving with the same velocity, and then to reduce the result found by the ratio of the density of compressed air to the density of water.

If the experiments upon which these conclusions are based, do not exhibit the precision of a physical experiment, a precision which the means at our disposal and the regular routine of the work would not permit us to attain, we believe that, considering the great length of the conduit, the amount of the pressures, the quantity and velocity of the air, and the duration of the observations, that these investigations present the character of thoroughly practical experiments.

THE PRINCIPLES INVOLVED IN THE CONSTRUCTION OF THE TELESCOPE.

By THOMAS NOLAN, B. S.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

II.

II. THE REFLECTING TELESCOPE.

Having considered the principles on which the simple refracting telescope is constructed, we will next explain the manner in which the properties of the reflection of light are utilized for astronomical observation by the reflecting telescope.

An image may be formed by reflection from a polished surface, wrought into a regular convexity, on the same principles of the divergence and convergence of the reflected rays, as by refraction through polished transparent surfaces.

If rays of light, falling upon a concave mirror, diverge from a point beyond the center of curvature, they will converge, after reflection, to a point between the principal focus, or focus for parallel rays, and the center of curvature. This point is called the conjugate focus.

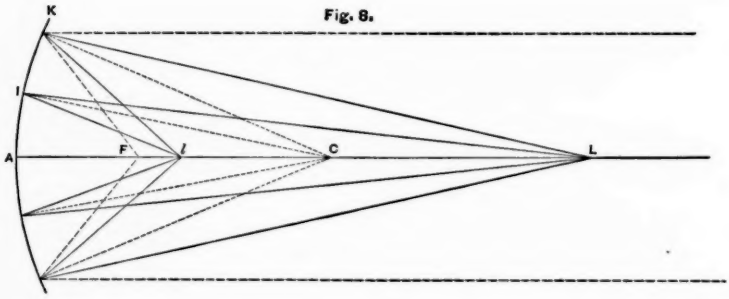
If light radiates from L (Fig. 8), it is reflected to l; if it radiates from l, it meets at L. If the radius of the mirror and the distance of one focus from it are given, the distance of its conjugate focus may be determined. As the angle L$K l$ is bisected by the radius KC, we have LK : lK :: CL : lC—that is, when KA is considered very small, LA : lA :: CL : lC, or, letting r=radius, LA : lA :: LA—r : r—lA. Hence, $\mathrm{LA} = \frac{r \cdot l\mathrm{A}}{2l\mathrm{A} - r}$, and $l\mathrm{A} = \frac{r \cdot \mathrm{LA}}{2\mathrm{LA} - r}$. If the luminous point is at C, all the rays will be "reflected back"

to the same point, and while the radiant point moves from C to infinity, the conjugate focus moves from C to F,—the principal focus.

Although there are many cases arising from the reflection of light at curved surfaces, due to position of mirror and direction of incident rays, it will be sufficient for our purpose to consider those particular cases of reflection which are involved in the construction of the various forms of the reflecting telescope.

By an examination of (Fig. 9), the formation of an image by a concave mirror is easily understood. The rays AC*a* and BC*b* from the object AB passing through the center of curvature C, fall perpendicularly on the surface MN, and are "reflected back" on themselves, so that the focus of the point A is somewhere on A*a*, and that of B on B*b*. By drawing another ray from A, we find it reflected to *a*, which is the focus of A; and by drawing another ray from B, we find it reflected to *b*, the focus of B.

Fig. 8.

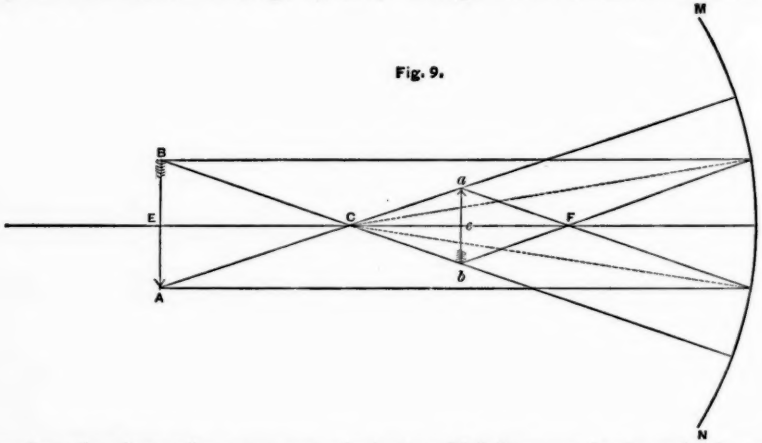


Since A*a* and B*b* cross at C, *ab* is smaller than AB, as *e*C is smaller than EC. When the object is a heavenly body, it is at a practically infinite distance, and the rays are parallel, and the image found half-way between the mirror and its center of curvature.

In regard to the convex mirror, the only case which happens in the reflecting telescope is that of converging rays incident upon a surface of such convexity as to render them less convergent.

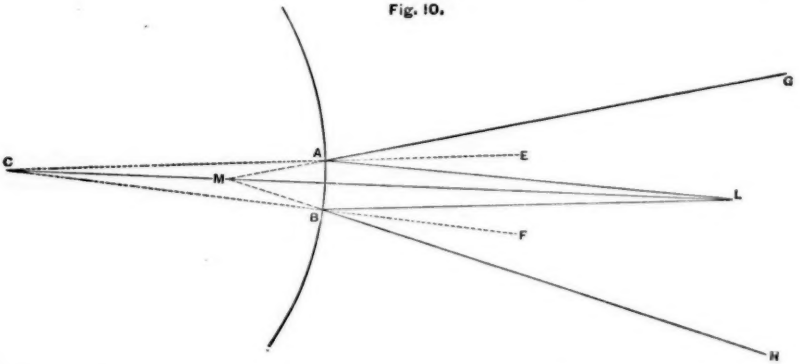
In (Fig. 10) we consider the light, after having been reflected from some converging surface, to proceed to the con-

Fig. 9.



vex mirror along the lines GA and HB, towards some point M. These rays, after reflection converge to L, and come to a focus in front of the mirror, at a point further in front than its center C is behind it, so that they have been rendered less convergent.

Fig. 10.

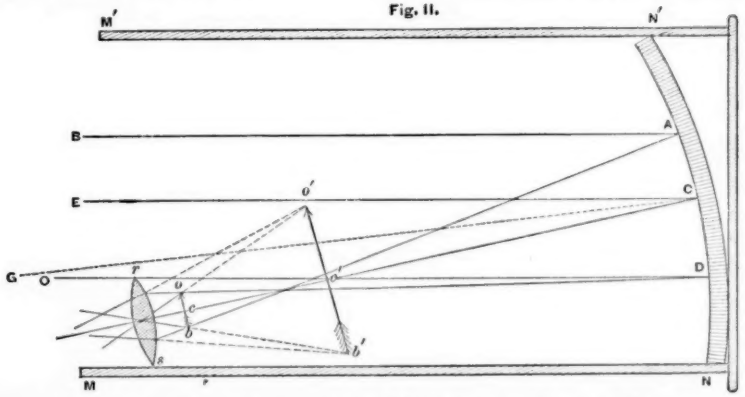


As the image formed by the concave speculum of a telescope is on the same side as the object, some arrangement is necessary to prevent the observer's head obstructing the passage of light to the speculum, and hence we have

1. FOUR DIFFERENT FORMS OF THE REFLECTING TELESCOPE.

(1). *The Herschelian Telescope.*—In this instrument the speculum is so tilted as to bring the image to one side of the tube. The concave reflector AD (Fig. 11) is fixed at the bottom of the tube MN M′N′, and tipped so that its axis GC bisects the angle EC*c*, between the axis of the tube and a line C*c* from its center to the edge of the opening of the tube. Parallel rays, falling on AD, are reflected to the side of the tube, where the image is formed, and where the eye-glass is placed to magnify it. The image *ob* is represented as being magnified by a single convex lens *rs*. As it falls between *rs* and its principal focus, a second, and enlarged, image is formed at *o′b′*. While the Herschelian has the brightest image of all the reflecting telescopes, with a given aperture, and possesses the advantage—so thoroughly appreciated by those in the habit of observing for many consecutive hours—of allowing the observer always to look downward, its disadvantages are still many. It cannot produce the finest definition, because the reflecting surface cannot bring the rays to an exact focus when they are thrown

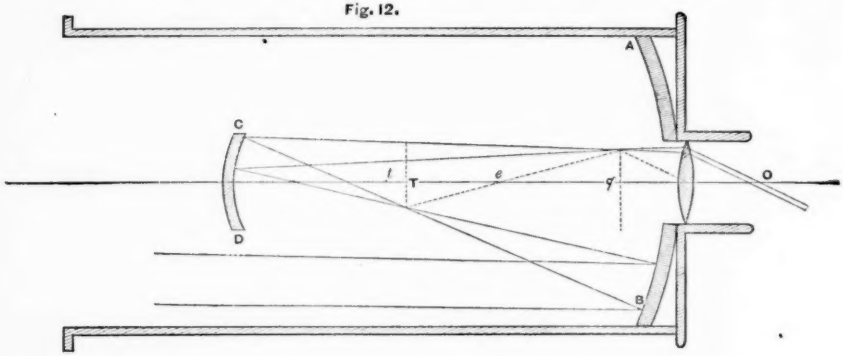
Fig. 11.



so far to one side of the axis of the tube; and the injury to definition, on this account, is so great that the "front view" plan has been almost entirely abandoned.

(2). *The Gregorian Telescope.*—The general principle of this construction is

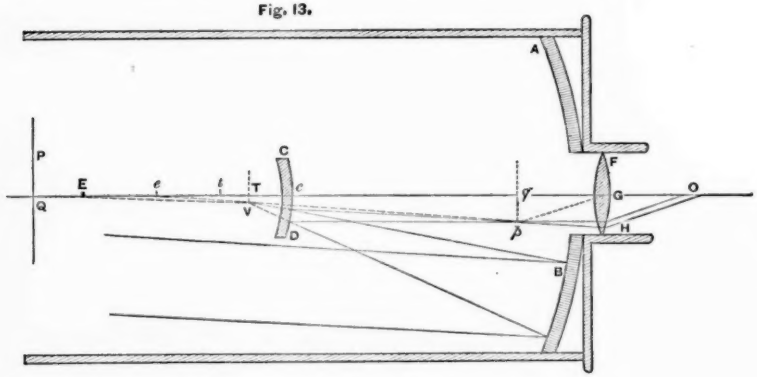
Fig. 12.



shown in (Fig. 12). AB is the speculum. A little beyond the image T, which is formed in the axis OT, is a small concave mirror CD. T is, with regard to CD, as an object placed between its focus *t*, and its center *e*; and CD forms a second image *q*, more or less distant from *e* as T is nearer to, or more remote from *t*. By moving CD nearer to, or further from T, *q* may be carried to any distance. The latter is commonly brought a little in front of AB, in which is an aperture, through which, by means of a proper eye-glass, *q* is viewed. The image appears erect, being reversed with regard to T, which is itself reversed with respect to the object.

(3). *The Cassegrainian Telescope.*—In this construction the smaller reflector CD (Fig. 13) is convex, and so placed that the image T falls between CD and its principal focus *t*. If CD be removed, and the axis GcE directed to Q in the object PQ, an inverted image TV, terminated by the lines QET and PEV, is formed in the principal focus of AB. But if CB be replaced the rays are intercepted by it before they reach T, and

Fig. 13.



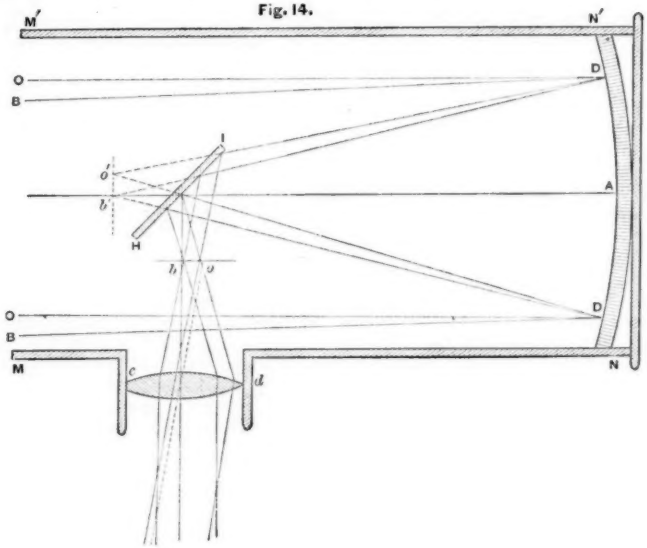
since TV falls between the surface CD, and its principal focus *t*, an erect image *qp* of TV is formed, and is terminated by the lines *e*T*q* and *e*V*p*. This image is viewed through the lens FGH, whose focal length is G*q*.

Objects appear inverted, for *pq*, which

is erect with respect to TV, or inverted with respect to PQ, is in or near the principal focus of FGH; the image upon the retina is, therefore, erect, and consequently the object will appear inverted.

(4). *The Newtonian Telescope.* — A representation of this telescope is given in (Fig. 14), in which DAD is a concave speculum, and IH a small plane mirror, inclined 45° to the axis of DAD. The image of OB, which would have been formed at *o'b'*, is caused by III to be formed in *ob*. The latter is observed through an opening made in the side of the tube directly opposite III, and furnished with an eye-glass *cd*.

Fig. 14.



If we let PQ (Fig. 15) be the object, *pq* its image, *nm* the image formed by the plane surface IeH, and *klr* a convex ey-eglass, whose focal length is *ln;* then *mn*, equal to *pq*, and corresponding to QP, is seen through *klr*, under the angle *mln* ; and QP is seen, with the naked eye placed at the center E, under the angle *q*E*p*. Since these angles have equal subtenses—*mn* and *qp*—they are to each other inversely as *ln* and E*q*, and, consequently, the angle which the object subtends at the center of the eye, when viewed with the telescope, is to the angle when viewed with the naked eye, as E*q* is to *ln*—that is as the focal length of the speculum is to that of the eye-glass. The fraction $\frac{Eq}{ln}$ is, therefore, the measure of the *magnifying power* of this telescope.

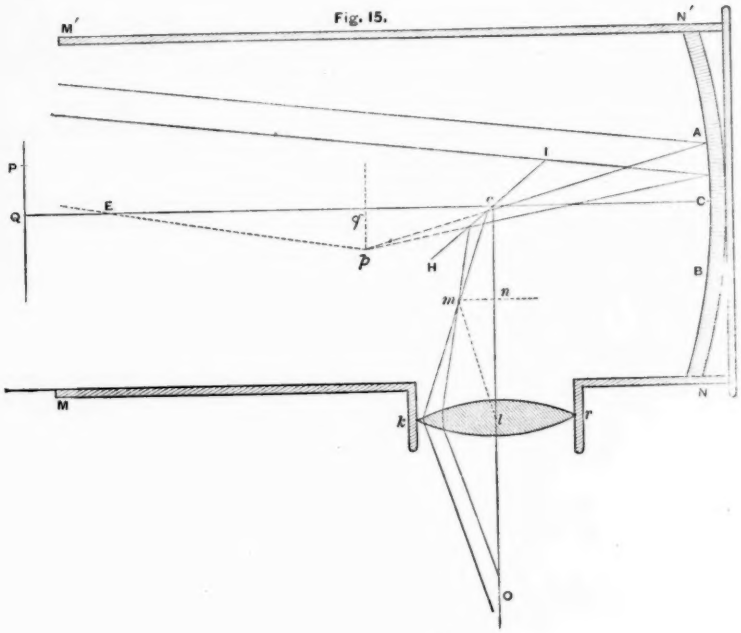
Having explained the optical principles underlying the construction of the most common forms of the reflecting telescope, we will next show what difficulties have to be overcome, in order to make large reflectors perfect.

Although the reflector possesses an enormous advantage over the refractor, in its inherent immunity from chromatic aberration, there is something else which quite lowers its position with regard to the latter, and that is,

2. SPHERICAL ABERRATION BY REFLECTION.

That all light falling in parallel lines on a concave spherical surface is reflected to a focus, is true only in a general sense. In (Fig. 16) MI is a section of a speculum, whose center of curvature is L, and DC, EG and HI, incident parallel rays. To find the focus of EG we draw LG, and make the angle FGL equal to EGL. But in repeating the process for HI it is reflected to K, and the further the rays from DC, the further from F is the light

Fig. 15.



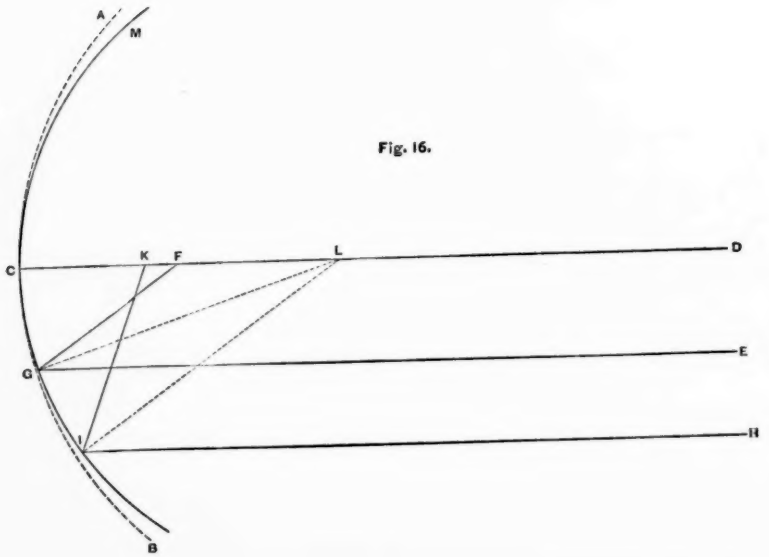


Fig. 16.

reflected. The edges of MI must, therefore, be thrown back to ACB, which makes its margin a part of a less concave speculum, and throws its focus further from itself, to F instead of to K. It is evident that this curve, which will throw all the parallel rays to one point, is the parabola; and the speculum, especially when of large diameter, is of no use without an *approximate* parabolic curve.

It is in the *polishing* of specula that the curve is altered from the spherical to the parabolic form, and it is here that the finest niceties of manipulation come into play, and the utmost skill and patience are required. That it is extremely difficult to give the parabolic figure, may be gathered from Sir John Herschel's statement, that in the case of a speculum 48 inches in diameter, and 40 feet in focal length, the distance between the spherical and parabolic surfaces at its edges was $\frac{1}{21333}$ of an inch.

In regard to the form of specula, it may be stated generally, that that is a good form which gives a good image; and that the geometrical distinctions between the sphere and parabola become mere theoretical abstractions in the figuring and polishing of specula, there being no practical mode of ascertaining, by any system of measurements on a scale, *what* form the surface has, apart from the optical effect on the rays of light.

III. THE COMPOUND REFRACTING, OR MODERN APLANATIC AND ACHROMATIC TELESCOPE.

In discussing the simple refracting telescope, it was assumed that spherical lenses bring rays of light, issuing from a point, to a focus without *dispersion*. But where the greatest accuracy is required, it becomes necessary to consider the imperfections of spherical lenses, and to discuss the subjects of *spherical* and *chromatic aberrations*, upon a perfect understanding of which the construction of the modern refractor depends.

1. THE "OBJECTIVE."

(1). *Spherical Aberration by Refraction.*—If the diameter of the lens VW (Fig. 17) is large in proportion to its radius of curvature, parallel rays are not brought to an accurate focus, but while the central rays cross the axis at F, the extreme rays intersect it at G, and intermediate rays at points between F and G. To

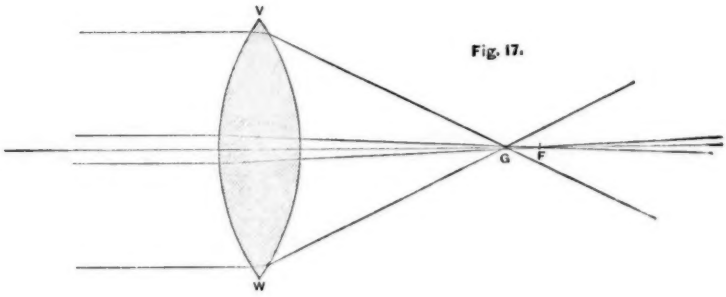


Fig. 17.

estimate the amount of spherical aberration in any case,* we calculate the course of a ray falling upon the border of the lens. AC (Fig. 18) is a section of the curved refracting surface, and QCq its axis. The refractive index is n. The distance QC, of the radiant point, is given, and also CD and AD co-ordinates of the point A. Hence, the normal AE and sub-normal DE may be found. Aq is the refracted ray required, cutting QCq in q.

sin incidence : sin AEC : : QE : QA.

sin E : sin refraction : : qA : qE.

$\therefore$ sin incidence : sin refraction

$$: : n : 1 : : \frac{qA}{qE} : \frac{QA}{QE},$$

* *Microscopical Journal*, Vol. VIII., p. 21.

$$\therefore \quad \frac{qA}{qE} = \frac{n \,.\, QA}{QE} = c \text{ (a known quantity).}$$

$$\overline{qA}^2 = c^2 . \overline{qE}^2, \text{ that is,}$$

$$\overline{qE}^2 + \overline{EA}^2 + 2qE \,.\, ED = c^2 . \overline{qE}^2,$$

$$\therefore \quad (c^2-1)\overline{qE}^2 - 2ED \,.\, qE = \overline{EA}^2.$$

$$\therefore \quad \overline{qE}^2 - \frac{2ED}{c^2-1} \,.\, qE = \frac{\overline{EA}^2}{c^2-1}$$

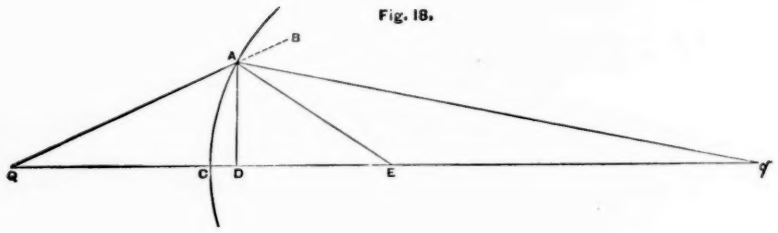
$$\therefore \quad \left\{qE - \frac{ED}{c^2-1}\right\}^2 = \frac{\overline{ED}^2}{(c^2-1)^2} + \frac{(c^2-1)\overline{EA}^2}{(c^2-1)^2}.$$

$$\therefore \quad qE = \frac{1}{c^2-1} \cdot \left\{ED \pm \sqrt{\overline{ED}^2 + (c^2-1)\overline{EA}^2}\right\}$$

From this formula the value of qE for any surface may be calculated. For lens of small aperture, the aberration is nal aberration then being only 1.07 times the thickness of the lens.*

No expedient has been discovered by which the spherical aberration of single lenses can be rendered less than 1.07 of their thickness; but if, instead of a double-convex lens, two plano-convex lenses be used, so placed that their convexities shall be turned towards each other, their combined aberration will be only 0.248, or about $\frac{1}{4}$ of their thickness, provided that the focal length of one be 2.3 times that of the other; and the spherical aberration may be wholly effaced by the combination of a double-convex lens C (Fig. 19) with a meniscus M, having suitable curvatures. In this case the convex side of M must be turned towards the object.†

Fig. 18.



in proportion to the square of the angular aperture of the lens; but for lenses of larger aperture, the aberration increases more rapidly.*

If n equals the index of refraction, r the radius of the anterior surface, and R that of the posterior surface of a lens, then, for parallel rays, the form for least aberration is expressed by the equation,

$$-\frac{r}{R} = \frac{4+n-2n^2}{2n^2+n}.$$ If $n=1.5$, the form for least aberration is a lens whose surfaces have their radii in the proportion of 1 to 6, with the side of deeper curvature towards the object—the longitudi-

Although it is hardly possible, in practice, to efface altogether the effects of spherical aberration, they have been so considerably diminished by the adaptation of the curvatures of lenticular surfaces, that in well-constructed telescopes they may be regarded as entirely removed

*If the length of the principal focus be taken as unity, the longitudinal aberration FG (Fig. 17) for lenses of different angular aperture will be as follows:

For 15°	the aberration will be	.....	0.025.
" 22°	"	"	0.062.
" 30°	"	"	0.150.
" 45°	"	"	0.375.

*Supposing the lens of least spherical aberration to have its aberration equal to 1, that of the other lenses will be as follows:

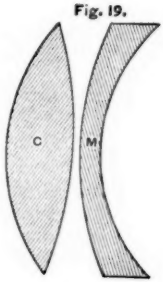
Best form	1.000.
Double convex or concave, with equal curvature	1.567.
Plano-convex, with convex side towards object	1.081.
Plano-convex with plane side towards object	4.306.

Plano-concave same as plano-convex.

†C.	1st Combination.	2nd Combination.
Focal length	10.000	10.000
Rad. of outer surface	5.833	5.833
" " inner "	35.000	35.000
M.		
Focal length	17.829	5.497
Rad. of outer surface	3.688	2.054
" " inner "	6.291	8.138
Focal length of combinations	6.407	3.474

for all practical purposes. The work has been accomplished by giving to the two sides of the lenses different curvatures, so adapted that the aberration produced by

Fig. 19.



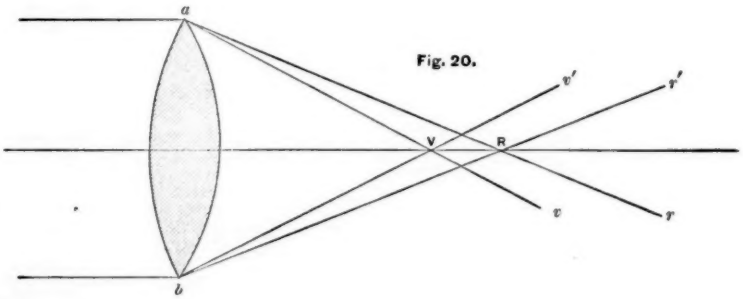
one shall be more or less counteracted by the aberration produced by the other.

(2.) *Chromatic aberration.* — White light, when refracted by a lens of any single transparent substance, like glass, is acted upon as by a prism, and dispersed into all the colors of the solar spectrum. This effect is shown in (Fig. 20), where V is the focus of the violet rays, which are most refracted, and R is the focus of the red rays, which are least refracted. A violet image is formed at V, and a red image at R, and the space VR is occupied by images of intermediate colors. An image of a point formed at V is violet, but surrounded by fringes of all the colors of the spectrum, the outer border being red.

To refract light, and still keep the colors united, it is necessary, after the rays are refracted, and thus separated, to use a substance of greater dispersive power, which brings the rays together again by refracting them only a part of the distance back to their original direction.

The problem is: can we make two lenses of different kinds of glass, with equal dispersive, but unequal refractive, powers? The researches of Euler and Dolland answer in the affirmative, by showing that the dispersive power of dense flint glass is about double that of crown glass, while the refractive power is nearly the same. Hence, a double-convex lens of crown glass AA (Fig. 21) is united with a plano-convex lens of flint glass BB, having a focus about double that of AA. BB corrects the chromatic aberration of AA, leaving about $\frac{1}{2}$ of the refractive power of AA as the effective refracting power of the

Fig. 20.

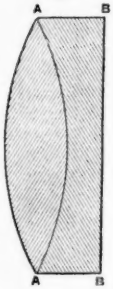


compound lens. No exact rule respecting the ratio of the curvature can be given, because the refractive powers of different specimens of glass differ, and the proper ratio in each case is found by trial. Having found it, the two lenses have equal aberrations, but in opposite directions, while AA refracting more powerfully than BB, the rays are brought to a focus at a distance a little more than double the focal distance of AA.

Having explained the general princi-

ples upon which achromatic lenses are produced, it will be satisfactory in a question of such importance to supply the mathematical details of its solution.

Fig. 21.



The problem is: to find what form must be given to two lenses of different refractive powers, to render the focal length of the compound lens, for light of any one refrangibility, equal to that for light of any other refrangibility. Let F′ and F″ be the focal lengths of the two lenses for light, of which the indices of refraction are n' and n'' for the media composing the lenses respectfully. Let f' and $''$ be the focal lengths for light of which the indices of refraction are m' and m''. Let F be the focal length of the compound lens. The converging power of the compound lens, on each kind of light, is equal to the sum of the converging powers of the two lenses, separately, on the same kind of light. The *converging power* of the compound lens, therefore, on the light whose indices of refraction are n' and n'', is $\frac{1}{F}+\frac{1}{F''}$, and its converging power on the light whose indices of refraction are m' and m'', is $\frac{1}{f'}+\frac{1}{f''}$. But since these two converging powers must be rendered equal, we have, $\frac{1}{F'}+\frac{1}{F''}=\frac{1}{f'}+\frac{1}{f''}$. We have, then, to assign such magnitudes to the radii of the surfaces of the lenses as will fulfill this condition. Let R_1 and R_2 be the radii of the surfaces of the first, and r_1 and r_2 those of the surfaces of the second lens. When F equals the focus of parallel rays, r and r', the radii of the surfaces, and n the index of refraction of any lens, we have, by a formula of optics:

$$F=\frac{rr'}{(n-1)(r-r')}.$$

By this formula:

$$\frac{1}{F'}=\frac{(n'-1)(R_1-R_2)}{R_1R_2},\ \frac{1}{F''}=\frac{(rc''-1)(r_1-r_2)}{r_1r_2};$$

$$\frac{1}{f'}=\frac{(m-1)(R_1-R_2)}{R_1R_2},\ \frac{1}{f''}=\frac{(m''-1)(r_1-r_2)}{r_1r_2}.$$

But since

$$\frac{1}{F'}+\frac{1}{F''}=\frac{1}{f'}+\frac{1}{f''},$$

we have,

$$\frac{1}{F'}-\frac{1}{f'}=\frac{1}{f''}-\frac{1}{F''}.$$

Therefore,

$$\frac{n'-m')(R_1-R_2)}{R_1R_2}=-\frac{(n''-m'')(r_1-r_2)}{r_1r_2},$$

and consequently,

$$\frac{n'-m'}{n''-m''}=-\frac{(r_1-r_2)R_1R_2}{(R_1-R_2)r_1r_2}.$$

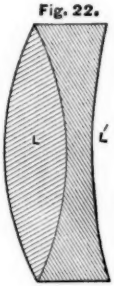
(n') and $(n''-m'')$ are the difference between the indices of the two lights having different refrangibilities, or the *dispersive powers* of the media composing the lenses for each of the two lights. If, then, the radii of the two lenses be so selected as to render $\frac{(r_1-r_2)-R_1R_2}{(R_1-R_2)r_1r_2}$ equal to the ratio of the dispersive powers of the materials of the two lenses for the two kinds of light, the latter are brought to the same focus by the compound lens.

Suppose the first a double-convex lens L (Fig. 22), with equal radii, and the second a double-concave lens L′, the surface of which, in contact with the first, has the same curvature with it, and, consequently, the same radius. Observing that when the convexities are turned in contrary directions, the radii have contrary signs $\frac{n'-m'}{n''-m''}=-\frac{(r_1-r_2)R_1R_2}{(R_1-R_2)r_1r_2}$ is now reduced to $\frac{n'-m'}{n''-m''}=\frac{r_2-R_2}{2r_2}$

Let us suppose that the double-convex lens is composed of crown glass, for which $n'=1.546566$, and $m'=1.525832$; and the double-concave of flint glass,

for which $n''=1.671062$ and $m''=1.627749$. We then have $\frac{n'-m'}{n''-m''}=\frac{.020734}{.043313}=\frac{r_2-R_1}{2r_2}$. Hence $r_2=23.47\times R_1$. The radius of the second surface of L′

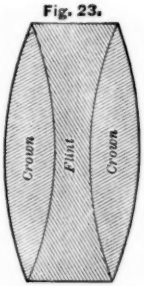
Fig. 22.



must in this case, therefore, be 23.47 times the radius of L.

Some of the earlier achromatic objectives were made of three lenses, as in (Fig. 23), a double concave lens of flint glass being fitted between two double convex lenses of crown glass. In June,

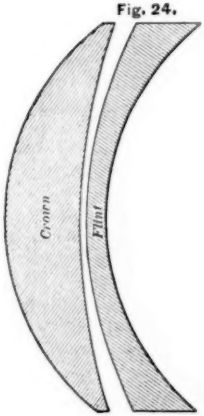
Fig. 23.



1860, Professor Steinheil communicated to the Royal Academy of Sciences at Munich, a notice of an object-glass of the form shown in (Fig. 24), executed according to the system of curves proposed by Gauss. The curves in this combination bear a considerable resemblance to the systems designed with express reference to the correction of spherical aberration, and for a long time object-glasses of this form were claimed by the most competent judges to exhibit a more complete achromatism, and in other respects more perfect definition, than was found with object-glasses of other forms.*

The problem presented to the mathematician, as to what shall be the form and disposition of the surfaces of two or more lenses composed of materials of different dispersive powers, which shall most effectually destroy the aberration of color and figure, is an indeterminate one; so that, for every lens of crown glass of positive focus, whatever the radii of its surfaces may be, a lens of

Fig. 24.



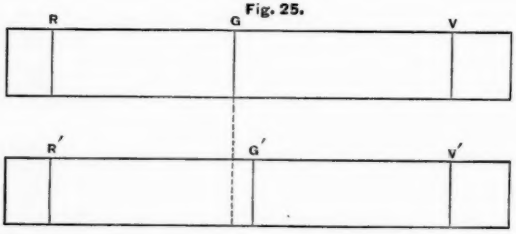
flint glass can be constructed which will form, when united with it, an achromatic and aplanatic object-glass. This allows a great range in the choice of curves, and a variety of conditions have been proposed by different authorities for determining the selection. The theory of telescope objectives is at this time being discussed by many able mathematicians, among whom, in our own country, are Professors Newcomb and Harkness, of Washington, and Professor Chas. Hastings, of the Johns Hopkins University. In regard to the form of objectives, Messrs. Alvan Clark and Sons, of Cambridgeport, Mass., whose reputation as

* Paper published by G. P. Bond in 1863 on "The New Form of the Achromatic Object-Glass introduced by Steinheil." Also, "Proceedings of the American Academy of Arts and Sciences." Vol. vi.

telescope makers is known throughout the world, in a letter to me, dated March 10, 1879, say: "Many forms may be used, but from our experience we have found that to *make the crown glass lens of equal curvature, and the flint glass lens nearly flat on the side next the eye*, is the most convenient, and *gives as good results as any other form;* of course, the curves must differ with different glass used; but the difference will be small." This is the form shown in (Fig. 21). If the dispersive power of the flint were just double that of the crown, the outer face of the former would have to be a plane surface to produce achromatism, but this is not generally the case. As no two specimens of glass made at different meltings have exactly the same refractive and dispersive powers, the optician must find the ratio of the dispersion of the two glasses, and then give the outer face of the flint such a degree of curvature as to neutralize the dispersion of the crown. Usually, this face will have to be slightly concave.

(3.) *Secondary Spectrum.*—The image formed at the focus of a so-called achromatic lens is not absolutely colorless. A difficulty arises from the fact that flint glass, as compared with crown, disperses the violet end of the spectrum more than the red end. If R, G, and V, (Fig. 25), are the centers of the red, green and violet in the spectrum given by a prism of the glass of which one lens is made, and R′, G′, and V′, are those of the other; and if the lenses are placed so as to counteract each other, and are of such curves that the red and violet are combined, the green remains slightly outstanding. If the second prism disperses the violet as much as the first one does, when they are reversed they exactly compensate red and violet. But the second acts more strongly than the first on the green, which is overcompensated; and if we weaken the second prism, so that the green and red are corrected, then the violet will be slightly outstanding. The defect is hardly noticeable in small telescopes, but in the immense refractors of two feet aperture, or upwards, this secondary aberration constitutes the most serious optical defect—a defect which, arising from the properties of glass itself, no art can dim-

Fig. 25.



inish. It has been suggested that this difficulty may be lessened by increasing the length of the instrument. But in doing this with glasses of such large size, engineering difficulties will be encountered which soon become insurmountable, and it is the opinion of many opticians and astronomers that "the limit of optical power for such instruments *has been very nearly attained.*"

In boring for water in the Wimmera district, Victoria, recently, a tree was passed through for 6 feet, at a depth of 250 feet, and the cup brought up several fruit stones similar to the nuts of plums; some were smashed, but the kernels were recognizable. It seemed evident that there was a grove of trees there.

THE CYCLICAL USE OF STEAM.

From "The Engineer."

By the cyclical use of steam, we mean to imply the use of a given weight of steam over and over again in a cycle. In the development of motive power air may be thus used. A given weight may be heated, expanded, made to drive a piston in expanding, withdrawn from the cylinder, cooled down, and reheated and expanded, over and over again. In some forms of hot-air engine the initial air in the apparatus might be used for ever without addition of any kind, were it not for imperfections in the apparatus which permit the air to leak away. Can steam be thus employed? That it can take the place of air, and that a hot-steam engine might be constructed as well as a hot-air engine, no one doubts; but whether it can or cannot be used over and over again in quite another way, is a question of very great importance, and to the consideration of this question we wish to direct the attention of our readers. What we are about to say may correct some misconceptions, and prove specially useful to many of our younger readers.

In the steam engine as usually made there is an inherent defect which is prejudicial to economy. This defect is that before steam can be used it must be made, and that after it is used it is thrown away. Under this system the greatest amount of work which it is possible in theory to get out of one pound of steam expanded, say eight times, in a cylinder with 7 per cent. clearance at each end of the stroke, the absolute initial pressure being 100 lbs. on the square inch, is 159,433 foot-pounds, and the heat converted into work will amount to 206.5 units, or 20.7 per cent. of all the heat communicated to the water in the boiler, assuming that the feed-water is introduced at 212 deg. Thus 79.3 per cent. of the fuel consumed is wasted even in theory, to say nothing of practical losses by cylinder condensation, radiation, and so on. As we have shown, this loss is a result of the system of working which involves first the manufacture of steam, and secondly the destruction of this steam in a condenser or its waste in the atmosphere. To make this proposition quite clear, we will assume that one pound of water at 212 deg. is introduced into a boiler. It will then be converted into steam having a pressure of 100 lbs. During the process of conversion 1001 units—omitting fractions—of heat will be taken up or absorbed by the water. The resulting pound of steam, occupying a space of 4.33 cubic feet, being admitted to a cylinder and worked in the ordinary way —and by assumption without loss by external cooling—will part with 206.5 units of heat which will be converted into work. The remaining 794.5 units will pass into the condenser, or will escape into the air, as the case may be. If it were possible to rescue even a fourth part of this 794.5 units, and convert them into useful work, it is evident that the economy of the steam engine would be enormously augmented.

It will be seen that the loss of 794.5 units, out of a total of 1001 units, is entirely due to the throwing away of the steam which has been used, and the consequent necessity for obtaining a fresh supply from the boiler. Any attempt to prevent the loss in question must therefore be directed to devising means for using the same steam over and over again in a cycle. In order to do this we must work—with 100 lbs. steam —our engine between 328 deg. as the maximum limit, and 212 deg. as the minimum limit of temperature; that is to say, the engine must receive steam at 328 deg., the temperature corresponding to 100 lbs. pressure, and reject it at 212 deg., the temperature corresponding to a pressure of 14.7 lbs. It is not necessary that the fall in temperature should be brought about wholly in the cylinder. To do this would involve $\frac{100}{14.7} = 6.8$-fold expansion; but for the attainment of the best result this ought to be the ratio of expansion. If it is less, then the steam would have to be reduced in pressure and temperature by external

cooling, or expansion without doing work, and either plan would represent a loss of useful effect. An engine constructed on this system would have no more to do with the external atmosphere than an ordinary condensing engine has. Its back pressure, however, would be just the same as in the case of a non-condensing engine, only in lieu of an atmosphere of air, the exhaust steam would always be discharged into an atmosphere of steam, contained in a vessel which would be in periodical free communication with the exhaust port. The efficiency of a pound of steam worked in such an engine would be identical in amount with the efficiency of a pound of steam worked in an ordinary non-condensing engine, and would be considerably less than equivalent to 150,433 foot-pounds; but we could afford to disregard this loss of efficiency which would—as will be seen presently—be made up many fold by the novel conditions of working, provided it were possible to use the same steam over and over again.

The cylinder of our imaginary engine has received 1 lb. of steam, but it will reject a pound of steam and water mixed, because a portion of the steam will be condensed in the performance of work. As much will be condensed as would be converted into steam of 100 lbs. pressure from water at 212 deg. by the 206.5 units of heat converted into water. As 1001 units are needed to thus convert 1 lb. of water, a very simple calculation will show that 206.5 units will convert .206 lbs. of water nearly; consequently there will be discharged from the cylinder .206 lbs. of water, and .794 lbs. of steam at 212 deg. The water will occupy a space of, omitting small fractions, 6 cubic inches, and the steam a space of 20.93, or in round numbers 21 cubic feet.

Now, it will be seen that to restore this mixture to the condition of steam of 100 lbs. pressure on the square inch, nothing is needed apparently save to re-evaporate the 6 cubic inches of water, and to restore the sensible heat lost by the steam. But 6 cubic inches of water will fill a space of $6 \times 270 = 1620$ cubic inches of steam at 100 lbs. only, or 5.43 cubic feet at 212 deg. This would not suffice to bring up the pressure to anything like that which it was when steam was first admitted to the cylinder. It is evident, therefore, that something more must be done than merely to re-evaporate the water which was condensed in the performance of work. Three courses are open: We may compress the steam until it occupies a space of 3.438 cubic feet, or we may apply heat to it until it assumes the required pressure, its volume remaining constant, or we may do both. If the steam be compressed adiabatically, all the work expended in compressing it will be returned during expansion. When compressed, communication would be opened between the vessel containing the compressed steam and that obtained by re-evaporating the water of condensation. We would then at once have 1 lb. of steam at 100 lbs. on the square inch to be introduced into the cylinder and do its work there. The cycle would thus apparently be complete, and for each pound of water which would otherwise have to be evaporated we would have now to convert into steam only, in round numbers, one-fifth of a pound. This represents an enormous saving.

As a matter of fact, however, the cycle is not complete. It is true that the work expended in compressing the steam may be all given back again, but it must be given back again in the cylinder, in lieu of work which would otherwise be available for driving machinery. To put this in a practical point of view, our imaginary steam engine must have a large compressing pump tacked on to it, and this pump would use up so much power that no economy would be realized.

As regards the second scheme nothing whatever is to be hoped from it, the temperature which the steam must acquire to even triple its pressure being far too great for adoption in practice.

Hitherto we have regarded steam as though it was a gas, and entirely distinct from the water of condensation. In practice, however, the steam would be delivered from the engine as a cloud; it would be saturated with moisture. It is evident that if by any device its volume could be largely augmented, even without increasing its pressure, by a moderate application of heat, that it could be used over again, not, indeed, in the first, but in a second or condensing cylinder. Now a dry gas expands by the application of heat at the rate of one-nth of

the volume per degree of temperature. The value of n being $461 + t$ where t is the sensible temperature; thus the senisible temperature of air being 212, then $461+212=673=n$ and expansion would take place at the rate of an increase of $\frac{1}{673}d$ of the volume for each degree. But wet steam constitutes a remarkable exception to the rule; n is not a constant but a variant, and the rate of expansion is three or four times that of dry steam under certain conditions. If then heat be applied to the steam as it escapes from the first cylinder, it may be assumed that a very considerable economy may be gained. We are not aware of this plan having been fully tried. Mr. Cowper devised many years since what was known as the "Cowper's Hot Pot," namely a receiver between the high and low pressure cylinder of a compound engine, in which, by the aid of a jacket and live steam from the boiler, it was intended to raise the temperature of the steam and dry it before it entered the low-pressure cylinder. The plan was tried, but it did not succeed in effecting any saving of fuel. But it would be wrong to condemn the system as a consequence, because the failure probably resulted from the fact that the steam was not really heated or dried in the hot pot; indeed, a rise of 1 deg. or 2 deg. was the greatest attained. There is much reason to believe, nowithstanding the failure of Mr. Cowper's scheme, that if the exhaust from the high-pressure cylinder of a compound engine was led through the tubes of a superheater of adequate size before it was admitted to the low pressure cylinder, that great economy would result; but it must not be forgotten that this arrangement would after all not provide for the use of the same steam over and over again. In other words, the steam, no matter how it was superheated or how many cylinders it traversed, must at last be thrown away; and it must be thrown away because it becomes, to use a word applied in a somewhat similar sense by Sir William Thompson, degraded. It loses both pressure and temperature, and this pressure and temperature cannot be restored by the re-evaporation of the water condensed during the performance of work.

It is, however, possible to use the same steam over and over again, but under conditions different from those which we have indicated. A pound of gaseous steam may be treated like a pound of air, and made to work as in an air engine. But the advantage, if any, possessed by steam over air is neutralized by the inconvenient circumstance that superheated steam exerts a solvent influence on cast iron, and cuts away cylinders and valve faces very fast.

It is not to be supposed that this is the first time that the use of steam many times over has been suggested. On the contrary, as we have shown, the economy to be effected by any scheme which would enable the idea to be carried into practice, even in an imperfect way, is so so great that many inventors have tried what they could do with the principle. The most recent effort in this direction is that of Mons. Testud de Beauregard, of the Rue Lafayette, Paris, whose invention possesses the charm of novelty at all events, to a considerable degree. The principle on which he proposes to work is very simple. The exhaust steam from an engine is reduced to a temperature of 212 deg. by passing it through a tube coiled in a vessel of water of somewhat less temperature. This steam is then returned into a chamber or regenerator through a pipe in which is a species of induction jet of high pressure superheated steam from a small boiler. The steam pipe to the engine opens into the regenerator, and a second jet drives the steam from the regenerator into the engine. That a jet possesses sufficient power to do this we know from experiments on the use of mixed air and steam, which we have ourselves carried out. But all the obstacles which we have named in the course of this article to the use of steam twice over appear to apply to this device. M. de Beauregard, however, pins his faith on the result of an experiment, which he thus describes: "Wrapped up in a wet cloth kept moist by boiling water, a glass mattrass with a long vertical neck was kept filled with saturated steam at 100 deg. Cent. This flask was connected to a superheating apparatus, so as to receive therefrom, through a special cock superheated and desaturated steam at 500 deg. to 600 deg. Cent. On opening the cock the flask was invariably shattered to pieces, owing to the instantaneous expansion to

which the steam it contained was subjected, and this happened although the large opening in the neck seemed sufficient for the sudden expansion of the steam." M. Beauregard considers that he has here made a new discovery: "The regeneration of negative steam, the instantaneous transformation of heat into expansive power." We need hardly tell our readers that M. Beauregard is mistaken, and that he is no nearer using steam twice over than any one else. The mixture of highly superheated with moist steam was long since proposed by Wethered, and the system has been largely used, and with good results, but with nothing like those anticipated by M. Beauregard. We mention his invention, indeed, as a warning to others. But we cannot help adding at the same time that so much uncertainity exists concerning the behaviour of fluids in such a condition of unstable equilibrium as is steam cooled down from a higher temperature to 212 deg. and saturated with moisture, that it is highly desirable that a very simple set of experiments should be carried out, to ascertain the pressures attained by condensing given weights of very highly superheated steam into given volumes of saturated steam. It is not impossible that higher pressures could be reached than theory points out as probable. We have already said that the expansion of steam at or near the boiling point is very irregular, and it is apparently irregular for equal increments of heats. There is here a possible source of economy not yet fully examined, but the broad fact remains that steam cannot be used over and over again through cyclical changes. At least the genius has not yet come amongst us who can show how it is to be done.

THE PROTECTION OF WOOD AND IRON BY PARAFFINE.

From "The Builder."

Dr. Eugen Schal gives some interesting information on this subject in the *Wurtembergische Gewerbeblatt.*

In chemical technology great difficulties sometimes arise when it is desired to manufacture, on a large scale, preparations which may be obtained with ease in the laboratory. In most cases the reason of this failure is the fact, that in the manufacture the use of glass, porcelain, platinum, &c., which successfully resist the effects of the various chemical agents must be dispensed with, and cheaper and less easily breakable materials, such as iron, copper, lead, and wood, substituted. Wood especially cannot be replaced by any other material in the wholesale preparation of muriatic lyes, although the same, according to the strength and temperature of the liquid, undergoes sometimes very rapid destruction.

Dr. Schal says he acquired this experience more particularly in 1874-77, in alizarine manufactories, and that he found in paraffine a means which efficiently protects the wood against damp, acids, and alkalis, and by which a great saving is effected. The wooden vessels used, especially tanks of pine wood, for boiling acid and alkaline lyes, as well as casks of oak of the heaviest weights, for separating acid alizarine lyes at a pressure of a half to two atmospheres, were generally totally rotton after a few months, but they lasted for two years when impregnated with paraffine.

Before treating with paraffine, however, the vessels must be thoroughly dried for about three weeks by leaving them in warm and dry air, in order to prepare the wood for the absorption of the paraffine solution in its pores. The latter solution is prepared in the following manner: A part of the paraffine is melted in a spacious metal vessel over a moderate fire, the mass being stirred, the boiler taken from the fire, best moved into the open air, stirred until the mass begins to congeal at the edge, and then about six parts of petroleum, ether, or sulphuret of carbon are poured in, and stirred until solution. The preparation is then put into vessels that may be hermetically closed, or it may be used at once. In preparing the paraffine solution great care must be exercised, as

paraffine, as well as petroleum, ether, or sulphuret of carbon especially, are very inflammable, and as even the vapor of the two last-mentioned substances, if mixed with air, may give rise to dangerous explosions. Those substances must, therefore, be kept in a cool space, far from light or fire, and well stoppered.

The wood is best saturated in dry and warm weather, as then it dries more quickly, and a smaller quantity of the solving agent is necessary. In winter six parts of the solvent generally do not suffice. This proportion changes with the quality of the paraffine and the temperature; paraffine solving with difficulty is better than the more readily soluble article. Vessels easy of access, such as tanks, tubs, &c., are coated in the open air with the solution as long as the wood will absorb it. The solvents evaporate very quickly, leaving the paraffine behind, so that two or three coatings may be laid on in succession. If the vessel is to be exceptionally well prepared, it is left for a day to dry, and then another layer of the paraffine given.

For vessels in which steam is used for boiling the liquids they contain, he applies after a few days a coating of oil varnish, because the melting point of paraffine is below the boiling point of water, and it is thus in time driven out of the pores by the water.

Instead of oil varnish, the vessels, after being well rubbed down, may also be coated with a thin solution of soluble glass, then dried and washed with diluted hydrochloric acid. The silicic acid thus formed clogs up the pores from the outside, and provides a protection to the paraffine against the hot water. For vessels which are used only with a moderate heat or cold, the coating of paraffine suffices perfectly. The paraffine is hardly dissolved by diluted cold alcohol, is not poisonous, and may also probably be used with advantage for vessels for keeping liquid. In the case of barrels, the solution was poured in simply after drying them; for an oak barrel holding nine to ten hectoliters, 1 kilo of paraffine dissolved in petroleum ether was required. All openings were then well closed and the barrel rolled about and over for about an hour, so as to bring all parts in contact with the solution. The barrels were finally left standing on their ends for half a day, after which time the remainder not absorbed was emptied, and used for the outside coating. Before applying the solution outside, however, the barrels must be well cleaned, for dirt naturally closes the pores of the wood. As these barrels were very expensive, and had to sustain a pressure of two atmospheres, besides being exposed to a high temperature, they received on both sides an additional coating of oil varnish. It is, however, necessary to let such a barrel stand in the open air at least a fortnight for drying, and, as a precaution, fire must be kept away from the barrel while being prepared. As a further precaution, in applying the solution inside, the workman must not be left alone, as it frequently happens that stupefying vapors from the solvent of the paraffine arise, which stupefaction, however, soon disappears in the open air. The oil varnish may also be diluted with petroleum ether, poured into the barrel, and then the latter rolled about, as above described; but many places escape saturation in this operation. After coating with varnish, the barrel is once more dried, and then filled with water, in order to force out the combustible gases. This is much to be advised, as an explosion once took place in consequence of a workman trying to enlarge a hole with a red hot iron, contrary to orders. After the last operation, the inner sides of the various vessels are rubbed down with a dry duster, so as to take off all loose particles.

If impregnation of wood is intended on a large scale, the wood is best stacked in iron boxes, the paraffine solution poured over it, the solution not absorbed drawn off after some time, the solvent forced out of the wood by means of warm air, and recovered by condensation in a cooling apparatus.

If the various manipulations are carefully carried out, the duration of vessels thus prepared is increased from four to six fold, while the outlay is comparatively small, leaving out of consideration that the contents of such vessels are frequently lost by the bottom being forced out.

Paraffine, melted with equal parts of linseed oil or rapeseed oil, is also useful for coating iron vessels, which, without a

substantial preservative, are very liable to rust in manufactories of chemicals.

Paraffine likewise protects skin efficiently against wet, alkalis (especially lime), acids, &c.

Dr. Schal says he often found that workmen in alizarine factories suffered much from sore, ulcerating and swollen hands, especially during winter. After the workmen began to use (twice daily) a solution of paraffine with rapeseed oil and petroleum, chapped hands became a scarcity.

The solution is produced by melting three parts each of paraffine and rapeseed oil, removing it from the fire, and adding eight parts of petroleum while stirring the mixture. Before using, the solution is stirred a little, and the hands rubbed with it while they are clean and dry. In larger factories, earthenware and tin vessels, filled with this ointment, are placed at convenient spots, and it is believed that the manufacturer, as well as the workman, will find this pay.

ON THE STRENGTH OF IRON AT HIGH TEMPERATURES.

By J. KOLLMANN.

From "Abstracts" of the Institution of Civil Engineers.

In this memoir the author gives the results of a series of investigations carried out in 1877–78 at the Oberhausen works upon the tension and resistance to compression of wrought iron and steel at high temperatures, which, together with other experiments, were undertaken to obtain a basis for a theory of the action of the rolling mill and of the construction of rolls. The materials investigated were of three kinds, namely, fibrous malleable iron, fine-grained iron, and mild Bessemer steel, the samples used being of the average ordinary qualities produced in the works. Two testing machines were used: in one the strain was applied by hydraulic pressure, and in the other by weights applied directly. The elastic limit was determined by a contrivance called a multiplier, consisting of a pair of unequal armed levers with set screws on the shorter arms, whereby they are attached to the test piece. These remain closed while there is no permanent elongation, but when the limit of elasticity is reached the arms separate, the divergence being read off on a divided scale attached to the longer sides.

The experiments were made with test pieces of two different sizes; those for the smaller hydraulic machine were either round, of 13 millimeters (0.51 inch) diameter, or square of the same dimensions on the side. Those for the larger one measured 40×10 millimeters (1.575×0.394 inch). They were brought up to the required temperature by heating either in a coke fire or a portable forge; two exactly similar pieces being used, one for the experiment and the other for the determination of the temperature, which was done by means of a water calorimeter of a somewhat special construction. The final temperature of the broken test piece was sometimes determined in the same way, but generally the loss of heat was computed by observing the time and applying the results of a table specially computed from masses of iron allowed to cool in the air for definite periods.

The experiments were made at temperatures varying from 20° to 1,080° Centigrade, and the progressive diminution in strength is expressed in terms of that at 0°, the latter being made = 100:

Centigrade.	Fibrous Iron.	Fine-Grained Iron.	Bessemer Iron.
0	100	100	100
100	100	100	100
200	95	100	100
300	90	97	94
500	38	44	34
700	16	23	18
900	6	12	9
1,000	4	7	7

—(*Verhandlungen des Vereins zur Beforderung des Gewerbfleisses.*)

THE USE OF CEMENTS.*

From "The Building News."

THERE is probably no more deeply-rooted conviction prevalent among architects than the belief we cherish in the excellence of Roman mortar. The Romans distinguished themselves among all the conquering nations of antiquity as mighty builders, and throughout every country which they subdued we find the remains of public works and buildings, more or less perfect, as evidences of their occupation and monuments of the skill and enterprise of their architects. The builders of Rome undoubtedly made use of the limestones of the countries in which they worked, and sometimes they came across good limes of a cementitious character, and at others they found only fat or rich limes. In the former case we find the structures which have escaped destruction at the hands of man still extant; in the latter, where the mortar was made of bad or unsuitable lime, the buildings have crumbled away and have become obliterated by natural causes. The secret of the excellence of Roman mortar, so often and so laboriously sought after, is to a great extent a delusion, and we praise the mortar of the ancients only because all the bad mortar has long since perished. It is nevertheless a fact that we owe indirectly to the Romans the discovery of all our modern cements, for it was in consequence of researches made respecting the durability of ancient mortars that the reason for what has been termed the hydraulicity of limes was explained early in the present century. To our own countryman, Smeaton, the builder of the Eddystone Lighthouse, and to Vicat and others on the Continent, must be assigned their due share of credit for these discoveries; and their labors have since been ably supplemented by the investigation of Pasley, John, Fuchs, and Pettenkofer. I will not occupy your time with more than a brief record of the gradual growth of our knowledge concerning cements, and I propose only to glance at the history of these materials, which is one of much interest. I wish rather to treat of the employment of cements for practical purposes, and to invite your attention to a brief consideration of the manner in which we have availed ourselves of the knowledge which we have acquired concerning cements and cement action. I must first dwell for a few moments, however, upon the use of mortar in London in times past, because my argument will involve a clear appreciation of this part of the subject. After the great fire in 1666, London, as we all know, sprang up, by royal enactment, as a brick city, and the quaint wooden buildings which had been the characteristics of the London of the past, were no longer recognized by the new Building Act, and were condemned, as they still are, by the district surveyors. There must at once have been a great demand for lime, and the quarries adjacent to the metropolis were placed, no doubt, under heavy contributions for the necessary materials. The chalk nearest to London, on the banks of the estuary of the Thames, and north and south—at Watford and Croydon—is the white, flint-bearing, or, as geologists term it, "the upper chalk"—one which yields a fat, pure lime, having little or no cementitious properties, and furnishing, therefore, a mortar of the worst possible kind. Further away—on the banks of the Medway, and on the chalk ranges of Dorking and Guildford, or northwards, in various parts of Buckinghamshire—we find the grey chalk a totally different substance, and one capable of yielding a lime of good quality. But it is impossible to examine the mortar of two hundred years ago without being convinced that it was white lime that our ancestors prized, and mixed with the smallest possible quantity of sand. The mortar of those days speedily dried, or obtained a false set, owing to the absorption of the water by the porous bricks, but it never became truly indurated, and, after all these years, it is found in the joints of many an old house in the city as a mere crumbling cake, which can be crushed into dust between the finger and thumb,

* A paper read before the Architectural Association, by Mr. Gilbert R. Redgrave.

and has no cohesive strength whatever. Just listen to what General Treusart says concerning this kind of lime: "Thus chalk-lime mortar, when wet, is a pulp or paste, and when dry it is little better than dust." No wonder at the clouds of fine powder which half-blind us when any work of demolition is in progress in the older parts of London; the only strange thing is that the brickwork holds together so long as it does.

It seems somewhat astonishing in these days of rapid building to read the specifications of even one hundred years ago only, and to learn the amount of labor then bestowed upon the preparation of even such mortar as this. Let me read you a passage from the "Builder's Price-book" of Batty Langley for the year of grace 1748. Speaking of what he terms "terrice mortar," probably trass, as he says terrice is a kind of sand brought from Holland, he tells us "the best terrice mortar is made with two bushels, &c., of hot lime, and one bushel, &c., of terrice, well incorporated by beating, and which quantity to beat well is a good day's work for a laborer." Think of this, poor overworked larryman, three bushels of mortar per diem "a good day's work!"

It was, I think, out of no disrespect for the white chalk lime, but rather from some strange belief in the color of the grey lime, that about the middle of the last century a fondness arose in London for what was called stone lime, such as that of Dorking or Merstham—that is a lime of stone color—for I can see no other reason for calling this chalk lime a stone lime, which it certainly is not. It was a fallacy dating back to the time of Vitruvous, that the harder or denser the stone from which the lime was burned, the harder the mortar made from it would eventually become. Smeaton was, perhaps, the first engineer to demonstrate this to be a mistake. So strongly was the truth of this fact believed in, however, that some have thought that an opportunity was taken of this error, to introduce the Surrey and Medway limes, under false plumes, by terming them stone-limes, to convey the impression that they had been burned from limestone rock; indeed, Smeaton tells us such was the case. My own opinion is that certain grey limes had gained the reputation of being strong limes, that is, capable of uniting large volumes of sand, and that it was the color which gave the name, in this instance, of stone lime.

Pasley says, respecting this commonly-received opinion of the strength of grey lime: "We found by repeated experiments at Chatham that one cubic foot of Halling lime (very similar to that of Dorking) weighed nearly the same when fresh from the kiln; and by the gradual addition of water, that it dilated to the same increased bulk in the state of quicklime powder; but, when worked up into mortar not too short for use, that it would not bear quite so large a proportion of sand as the common chalk lime had done; this experiment leading to a result in opposition to the common opinion amongst the builders in the metropolis, which is that the Dorking and Halling limes, as being stronger (limes), will, when made into mortar, bear more sand than common chalk lime."

We may assume that this rise of the grey lime in public favor was partly due also to the increased facilities of carriage, by means of which the better limes were able to compete with the fat limes, which had been hitherto more readily obtained around London. Whatever may have been the reason for this preference, practical builders, doubtless, soon found that the grey chalk lime yielded a far better mortar and would set harder with more sand than that made from the white chalk and pure lime; but "Dorking stone-lime" continues to this day a favorite piece of specification idiom.

The natural cement stones of the neighborhood of London were discovered by Dr. Parker, and specified for cement-making by Messrs. Wyatt & Parker, in 1796. They patented the mode of making what was called Roman cement, by means of calcining the septaria or masses of nodular limestone found in the London clay. In course of time it became known that very similar results could be obtained by combining mixtures of clay and lime or chalk mechanically, and artificial cements, such as those of Vicat and Pasley, became largely employed. This manufacture paved the way for Aspdin, with his Portland cement, patented in 1824, but it was not until 1847, or thereabouts, that the manufacture of Portland cement was perfected, and that what we

now regard as Portland cement was made use of upon any scale.

I have said thus much on the history, in order that I may prepare the way for my inquiry into our mode of using these cements, and glance at the extent to which they have supplanted lime. This may enable us perhaps to ascertain the causes of our failure, and properly to appreciate the advantages we should gain from the more extended use of cements.

I am going to maintain that in good Portland cement we possess the best building material of the day, infinitely better than half the rubbish we make our houses of or pave our streets with, and a hundred-fold better when used as mortar than the compound we still go on specifying, as if we knew no more than our grandfathers of the properties of limes and cement. I trust I am not heretical in these matters, but I am so firmly convinced that lime, as now employed, will shortly become obsolete, or nearly so, as a building material, that I am able to speak out boldly in favor of cements. This brings me to my subject —the use, or, rather, the uses, of cements; for we are almost daily adding to our store of knowledge concerning the numerous constructive purposes for which cements may be made available.

Before going further, I wish to be clearly understood in respect to the meaning of the term "cement." By the word "cement," as it is now used in building, a substance is implied which, when treated with water, will set or indurate without change of form. Limes of every variety show more or less energy to change their physical condition, when water is poured over them. Pure limes, such as those made from Carrara marble or white chalk, instantly unite with the water or become hydrated, expand to two or three times their bulk, develop intense heat, and fall to a powder. Very hydraulic limes, under the influence of water, show at first hardly any sign of action. They are termed by builders very "dead," and only after the lapse of hours, or even days, crumble into coarse gritty fragments. Such limes, if ground, or mechanically reduced to an impalpable powder, may solidify without heat or apparent expansion, and acquire a set of the same nature as Portland cement. These limes are true natural cements. Between the active pure limes and the natural cements are an infinity of hydraulic or partially hydraulic limes, some of which, namely, those of a dangerous type, will at first set under water, which is what the term "hydraulic" really implies, or in air, and gradually fall to pieces; while others, on the contrary, will at first crumble to a fine powder, which powder, however, on being worked up with more water, will set, after the manner of cement. Limes of this kind are termed by Vicat "intermediate limes," as they partake of the character both of limes and cements, and are intermediate in their action between the two. The eminently hydraulic limes of the lias formation, which are ground and sold as "lias cements," are natural cements of the former class; while all argillaceous limes, which will go abroad when treated with water, and subsequently set when made up with sand, belong to the latter class.

It may be useful here to point out that Portland cement (which is one of the very highest quality when properly made) sometimes, owing to defects in its manufacture, presents more the characteristics of an intermediate lime than those of a true cement. Thus it may, from imperfect calcination, faulty proportions, or undue admixture of the ingredients, blow and fall to pieces, after having become set, or it may crumble and fail to acquire cohesion when mixed with water; or, lastly, it may set so slowly as to be scarcely capable of being used for cementitious purposes at all. Portland cement, in fact, although the manufacture has now been brought to great perfection, is not wholly free from fluctuations in composition, which, in former times, brought great discredit upon the material, and which during the early days of its employment, caused it to suffer by contrast even with Roman cement.

The next consideration is the cause of cement action, that is, the explanation of the facts I have just been describing. Why do some limes swell up and fall to pieces when treated with water, while others remain wholly inert? The cause of hydraulicity was, to a certain extent, explained by Smeaton, who found by exposing the Aberthaw lime to the action

of acid, that he obtained a residue of clay, and that all good "water-limes" examined by him left this sort of residue, while the pure limes, which were devoid of hydraulic properties, were entirely dissolved. He therefore rightly attributed this peculiar action to the presence of the clay. In his own words, he says: "In burning and falling down into a powder of a buff-colored tinge, and in containing a considerable quantity of clay, I have found all water limes to agree." Smeaton, who owned that he was no chemist, does not appear to have known the true reason for this action. It remained to Saussure to announce that this property depended solely upon the presence of the clay, while Descotils, in the year 1813, pointed out that the cause of the phenomenon was due to the presence of a large quantity of silicious matter, disseminated in very fine particles throughout the texture of the mineral. The chemistry of the action of cements and the formation of silicates in the kiln, which silicates become hydrated and rearrange themselves in consequence of the difference of their affinities, in the presence of the water, was first thoroughly explained by John, and the theory was perfected by Fuchs, of Munich. The study of this branch of the subject is one of great interest, and those who wish to pursue it further may do so by consulting the essay on lime in Knapp's "Technology."

It is strange that, although this action is in the main a chemical one, it can be greatly influenced by purely physical causes. To illustrate this, I will quote a recent and curious experiment of Dr. Knapp's in the laboratory at Brunswick. The avidity of quick lime for water is one of the strongest we know of, and the rapidity of the combination of the lime causes so much warmth to be evolved that the particles are immediately raised to a red heat. Conflagrations, we know, often occur from what is termed the slaking of lime. Now, if quick lime be reduced to powder in a pestle and mortar, and this powder be tightly rammed into a hollow cylinder perforated with minute holes, and fitted with screw caps to close the ends; on placing this lime-cylinder in water, the moisture can only reach the enclosed quicklime very gradually and in very small quantities; the result is, that instead of slaking to a powder, the lime becomes converted by its hydration into a very hard and solid mass, as different as can well be imagined from ordinary slaked lime. Here a well-known chemical action is changed by purely physical means. Some chemists have thought that in the case of mixtures of lime and silicates, that is, in those limes which are more or less hydraulic, the particles of quicklime, being coated over with an envelope of silicious matter, the water is only permitted to approach the lime very gradually, as was the case in the cylinder experiment I have described; and this theory has also been put forward by a German chemist to explain the reason for the peculiar action of General Scott's cement, or selenitic cement, as it is termed. I am afraid I am devoting more time than you will care for to these chemical questions, but I think they will enable us to appreciate better the action of cements. To sum up briefly the foregoing facts: Pure limes which, after falling into a powder, are made up into a paste and mixed with sand, yield mortars which have no inherent setting power, and can only become indurated by the slow and gradual recombination with carbonic acid. This re-formation of the carbonate can only proceed where atmospheric air, or water charged with carbonic acid gas, can penetrate, and the centers of thick walls, even after centuries, are often found with the mortar still in the state of putty, as when first used. Cements, on the contrary, owe but little to the atmosphere; indeed, true cements indurate better beneath the water than in the air. They possess in themselves the power of solidifying or becoming indurated, and attain their greatest strength in a few years at the most. It is a question which can scarcely be said to have been finally settled how long cements continue to harden; indeed, cements vary so much in this respect that the time differs in almost every sample, according to the composition and the degree of firing. Cements of the Roman type stand at one end of this scale, for many of them attain their full degree of hardness or tensile strength in from twenty to thirty days; while dense, well-made Portland cement of the highest quality would seem, from Mr. Grant's experiments, to continue to improve for seven years, and

constitutes the other extreme of the scale.

In speaking of cements, I have purposely avoided all mention of that class of substances which, when added to rich or fat limes, impart to them hydraulic properties. These materials are puzzuolana, trass, arenes or volcanic sand, and many kinds of calcined argillaceous earth. There can be little doubt that all these substances owe their influence on mortars to the soluble silica contained in them. By soluble silica, I mean that variety of silicic acid which when treated with acids will gelatinize. Silica when heated to bright redness in the presence of bases acquires this soluble form, and most calcined clays, and volcanic minerals, which have been exposed to high temperatures, are more or less rich in gelatinous silica. Mortars compounded with pure lime and a sufficient quantity of substances capable of converting them into cements become, for the purpose of the arguments I am anxious to place before you, equivalent to cement mortars. Unfortunately, however, these mortars are rarely employed, except by engineers for docks, foundations, and other similar purposes, where the solvent action of water is dreaded. Occasionally, when, owing to the difficulty of obtaining good sand, the builder employs with fat limes, burnt ballast or broken bricks, which are artificial puzzuolona, a mortar which sets surprisingly hard is obtained. Such good mortars are, however, exceptional, and their excellence is due only to the action of the "aggregate," and not in any way to the quality of the lime.

I now return to my subject, and propose to place before you the arguments in favor of employing cements instead of limes for mortar-making. First, cements will unite much larger quantities of sand and building materials into a homogeneous mass than limes, and they are therefore more economical to use than limes. I am sure that the plea of economy is one of the very strongest arguments of the present day, and therefore, though this is not my best plea, I introduce it first. Rather than take the price-book values of lime, cement and sand, and with them construct an imaginary set of tables to show how the prices would work out, I will avail myself, on the present occasion, of the admirable series of experiments recorded by Mr. Colson in a paper presented to the Institution of Civil Engineers in 1878, in which this subject is most fully and ably dealt with. I am the more tempted to place before you Mr. Colson's figures, because he has, with the painstaking care and accuracy which mark all his observations, not only given us the cost of different mortars, but also the actual strength of each of the various mixtures. His experiments will be all the more interesting, I think too, because the paper containing them was not read and discussed at a meeting, but formed one of the selected papers, published in Vol. 54 of the Proceedings of the Institution of Civil Engineers. It has, therefore, hitherto, not attracted that share of attention from architects and engineers which the importance of the subject demands. I will convey to you Mr. Colson's observations as far as possible in his own words:

"The object of these experiments," he tells us, "was to ascertain what proportion of Portland cement and sand would produce a mortar equal in strength to, and as convenient to work as, grey lime mortar, mixed in the proportions ordinarily adopted for constructive purposes." I may here observe that the difficulty in the use of cement mortars with large quantities of sand is their want of plasticity, and it is necessary to contrive means to overcome this, or the workmen will not employ them, except in a very liquid, and therefore very objectionable, condition. This tendency to shortness can be obviated by introducing chalk, lime dust, loam, or other substances which produce a fat unctuous paste when treated with water, but all these materials tend to weaken the mortar. Still, it has been found, from careful experiments, that within certain limits it is possible to introduce even clay (which is, perhaps, the cheapest diluent which can be obtained) without reducing to any very serious extent the tensile strength of the mortar. The following series of experiments is very interesting, bearing as it does directly upon this point. The mortar was, we are told, in each case mixed to a workable consistency, equal, in fact, to the condition in which it could be used in the work. Mr. Colson's testing was carried out by by means of

briquettes, similar to those used in ascertaining the strength of Portland cement, having a neck of 1½ in. square, equal to a sectional area of 2¼ square inches. The mortars remained in the moulds until sufficiently hard to admit of removal. At the expiration of six months the blocks were tested for tensile strength, the results being shown in the first table. Mr. Colson says, respecting the samples of common lime mortar, that "the induration or chemical set had penetrated only to the extent of ⅛ in. to $\frac{3}{16}$ in.; but, in a majority of instances, only ⅛ in. The remainder of the area of the fracture had only dried, and could be crushed in the hand without any great exertion of force." The cement mortar with six, eight, and ten parts of sand, was, we are told, of "such a raw, harsh character, that it would be practically impossible to use it in a satisfactory manner. In order, therefore, to render it somewhat more convenient for working, a small quantity of lime or yellow loam was added, thus rendering the mortar more plastic and tenacious."

"The result of further experiments shows that the addition of lime and loam reduces the initial strength of cement mortar considerably, the reduction due to the addition of loam being more marked than by the addition of lime. The quantity of unslaked lime or loam, viz.: one-twelfth the bulk of the sand was found to be as small a proportion as could be used to give the necessary tenacity."

Mr. Colson tells us that the experiments made with these mortars in brick joints "were not altogether satisfactory, inasmuch as the appliances at hand were not sufficiently accurate and delicate to justify a ratio of comparison. It may, however, be stated that the general result went to prove that the adhesive power of mortar, mixed in the proportions of eight of sand to one of cement, with the addition of loam, was superior to grey lime mortar mixed in the proportion of two of sand to one of lime."

The second table shows the comparative cost of these different descriptions of mortar. As Mr. Colson points out, "such estimates must be received with caution, because difference of locality would exert a great influence upon the cost of production. The following statement is a close approximation of the cost of the several descriptions of mortar, the charge for labor and water, and also the bulk of mortar produced, being in each case the mean result of experiments."

The second argument in favor of using cement in lieu of lime is, that cement possesses an adherent chemical set, or power of induration, whereas fat limes can only become indurated either by the slow and gradual influence of the carbonic acid contained in the atmosphere, or in consequence of the materials mixed with it to make the mortar. I have already, in the earlier part of this paper, dealt with the setting power of cements and the re-carbonation of limes. But it may be as well to glance at the facts again, to see what they imply. Cement mortar has everything necessary in itself, in whatever position it may be placed, to become hard; all that it requires is a reasonable amount of moisture. In the center of walls, in trenches and foundations, and even under water, the indurations of cement compounds proceeds steadily, until in due time the mass acquires the hardness of stone. Lime mortar, when fat limes are used, soon gets a thin skin of carbonate formed at the surface and joints, and the very formation of this exterior skin or coating at once presents a formidable obstacle to the induration of the lower or interior layers of the mortar. These merely dry into a crumbling porous powder, with little or no strength, and which, if the air cannot reach them, are no harder in one hundred years than in a twelvemonth. Alberti states that he had seen lime in an old ditch that had been abandoned about two hundred years "which was still so moist, well-tempered and ripe, that not honey, or the marrow of animals, could be more so." What a contrast to this is presented by the fact that a week or two back, while a barge at some works upon which I am engaged in Staffordshire was being unloaded, a sack of Portland cement fell into the water; it could not be fished up for a day or two, but when recovered it had become converted into a stone-like mass moulded to the exact form of the sack.

Perhaps I shall be reminded that mortar joints are not by any means generally such worthless affairs as cement advo-

TABLE I.—COMPARATIVE STRENGTH OF GREY LIME AND PORTLAND CEMENT MORTARS; ALSO PORTLAND CEMENT MORTAR, WITH THE ADDITION OF LIME AND LOAM.

No.	Number of tests.	Proportions.				Breaking strain on 2.25 square inches in lbs.	Breaking strain per square inch in lbs.	Ratio compared with lime mortar.	Ratio as compared with cement mortar.	Remarks.
		Sand.	C'ment	Lime.	Water					
1	17	2.00	—	1.00	1.33	61.06	27.13	—	—	Three samples of Grey lime. Water includes that required for slaking lime.
2	27	2.00	—	1.00	1.33	106 07	47.09	—	—	
3	27	2.00	—	1.00	1.33	82.00	36.44	—	—	
1	15	6.00	1.00	—	1.25	233.53	103.79	2.81 to 1	—	Cement taken from bulk in store.
2	20	8.00	1.00	—	1.66	154.80	68.80	1.86 to 1	—	
3	35	10.00	1.00	—	2.00	112.88	50.16	1.36 to 1	—	
1	70	6.00	1.00	0.50	1.50	165.31	73.47	2.00 to 1	0.70 to 1	Water includes that required for slaking the lime.
2	74	6.00	1.00	0.66	2.00	132.62	58.94	1.60 to 1	0.85 to 1	
3	85	10.00	1.00	0.83	2.50	95.27	42.34	1.14 to 1	0.84 to 1	
				Loam.						
1	21	6.00	1.00	0.50	1.00	136.80	60.80	1.64 to 1	0.58 to 1	Yellow loam, fresh dug and rather damp
2	25	8.00	1.00	0.66	1.33	86.48	38.43	1.04 to 1	0.55 to 1	
3	19	10.00	1.00	0.83	2.00	64.50	28.66	0.77 to 1	0.57 to 1	

TABLE II.—STATEMENT OF APPROXIMATE COST OF MORTARS.

Description.	Proportions in cubic yards.				Cost of material.	Cost of labor and water.	Total cost.	Produce of mortar in cubic yards.	Cost per cubic yard.
	Portland cement at 45s. 8d. per cubic yard.	Grey lime at 14s. 6d. per cubic yard.	Loam at 2s. 9d. per cubic yard.	Sand at 2s. 9d. per cubic yard.					
					s.	s.	s.	cu. yds	s.
Grey lime mortar.....	—	1.00	—	2.00	20.00	6.62	26.62	2.25	11.83
Portland cement mortar No. 1.....	1.00	—	—	6.00	62.19	6.84	68.23	5.90	11.56
Portland cement mortar No. 2.....	1.00	—	—	8.00	67.69	7.80	75.49	7.60	9.93
Portland cement mortar No. 3.....	1.00	—	—	10.00	73.19	9.57	82.76	9.30	8.88
Portland cement and lime mortar No. 1.....	1.00	0.50	—	6.00	69.44	8.68	78.12	6.40	12.20
Portland cement and lime mortar No. 2.....	1.00	0.66	—	8.00	77.27	11.20	88.46	8.25	10.72
Portland cement and lime mortar No. 3.....	1.00	0.83	—	10.00	85.22	13.78	99.00	10.15	9.75
Portland cement and loam mortar No. 1.....	1.00	—	0.50	6.00	63.56	6.23	69.79	6.10	11.44
Portland cement and loam mortar No. 2.....	1.00	—	0.66	8.00	69.53	8.05	77.58	7.90	9.82
Portland cement and loam mortar No. 3.....	1.00	—	0.83	10.00	75.47	9.97	85.44	9.75	8.76

cates are wont to describe them, and that even when white chalk lime or mountain limestone is used, the crystallization of the hydrate of lime round the particles of sand presents the appearance of some slight induration. I will grant that such is to a certain extent the case, but I believe it will more often be found that this trifling amount of induration is due to the sand employed in forming the mortar. Lime has the power of slowly attacking silica, even in the form of quartz, and most sands present other bases favorable to the formation of compound silicates. We thus get in very old mortars a small percentage of silicate of lime, which can only be accounted for by some such action as this. Of course, when the lime is presented with a sufficient quantity of a substance of the nature of puzzuolana, to enable it to form silicates in the work, we obtain a cement action differing but little from what would result from the use of true cements. Some writers seem to have thought that it might be cheaper, and more generally convenient, to form the cement in the work by compounding a mortar of a fat lime with the requisite quantity of calcined silicious clay; but this plan, after having been tried on the Continent, has been abandoned in favor of the mode, patented by Vicat and St. Leger, of making an artificial hydraulic lime from a mixture of chalk and clay. This manufacture is still carried on upon a considerable scale round Paris, at Issy and Meudon, and the use of pure lime, so vigorously denounced by Vicat, has since his time been to a great extent abandoned (at any rate, upon public works) in France. It cannot be said that here in England we have taken to heart the lessons we have learned, and the unscientific use of lime burned from the hard limestones of the North of England, and from the white chalk in our southern and eastern counties, still continues unchecked.

A third reason for employing cements in preference to limes is, that a method has been discovered by General Scott by which limes can be converted into cements by a very simple process, and at a very moderate cost. Perhaps you will allow me to glance briefly at this invention, as it is one imperfectly understood. About twenty-five years ago General (then Captain) Scott, of the Royal Engineers, found that a sample of grey lime, burnt in a common fireplace, with a smothered fire, had acquired properties very different from those of the same lime if prepared in a clear bright fire. He at first thought that this peculiar result was due to the formation of a subcarbonate of lime, owing to the imperfect combustion of the fuel, but subsequent experiments caused him to abandon this view, and to adopt the theory, which he ultimately found to be the correct one, that the change in the character of the lime was due to the presence of sulphur which had been absorbed from the ashes of the coal. This fact led to the invention of what was called Scott's cement, a material which was prepared as follows: Tender burnt grey chalk lime, made from a lower chalk, containing from 10 to 15 per cent. of silica and alumina (as, for instance, that of Lewes, in Sussex, or Borham, on the Medway), was re-heated to bright redness in shallow kilns or ovens, having perforated floors or hearths. When the lime was sufficiently hot, pots of sulphur were placed beneath the floors, and this sulphur was at once set fire to by the heat of the kilns. The fumes of the burning sulphur thus rose around the lime, and a coating of sulphate of lime was formed over each of the lumps. The lime was then ground between mill stones, and Scott's cement ready for use was obtained. As it appeared that this cement owed its peculiar properties to very minute quantities of sulphate of lime, intimately mixed with it, General Scott thought it might be possible to prepare it in a cheaper way, as, for instance, by sprinkling lump lime with sulphuric acid, or mixing ground lime with plaster of Paris; but though each of these plans was tried most carefully, it was found to be impossible to secure uniformity by any other than the gaseous method before described. Many years later, during the building of the 1871 Exhibition, General Scott found that if the selenitic lime, however prepared, were first ground in a mortar mill to a creamy paste, and the sand then added, a very good cement action was secured, and he made a selenitic cement, as he has termed it, from a careful mixture of ground hydraulic lime and sulphate of lime. This cement, if

used as directed by General Scott, will bind together six parts of sand into an extremely hard mortar, and will make a good concrete with nine parts of ballast. My argument in favor of the use of cements is, therefore, greatly strengthened by my being able to point to such a material as selenitic cement.

The question of the kind of sand to be employed hardly enters into my present subject. I may mention, however, that in using cements, in order to secure their utmost strength, clean sand is eminently necessary. Sharp large-grained sand makes better work than find sand, and there seems scarcely any objection to clean sea sand, except that for internal plastering it is liable to become damp on changes in the weather, as the salt absorbs moisture. Salt sand makes stronger cement mortar than pit or river sand, provided all are equally clean.

I wish, in conclusion, to say a few words about the use of cement in concrete. In this direction I am convinced that hitherto very little has been accomplished, and we plod on here in London with bad bricks and bad mortar, as if there was no escape from a thoroughly vicious system of building, which ought to have been abandoned with the building of the Tower of Babel. Concrete making and the numerous uses of cement concrete is a subject in itself for a long paper, and I can only point to a few directions in which the applications of concrete appear to deserve attention. I am disposed to affirm—at any rate, I will do so for the purpose of argument—that as London, from its peculiar position, is and must continne a brick city, we ought, with our present knowledge of the properties of cements, to make our bricks much smaller, to serve as mere "aggregates," or, what would be better still, we should calcine our brick earth in heaps, as ballast is made, and unite this burnt clay into monolithic structures with Portland cement. I cannot perceive any legitimate argument in favor of selling under-burned, misshapen, discolored lumps of calcined clay at so much per thousand, in order to enable builders to charge £14 and upwards per rod for sticking them together into walls. Far better would it be to burn the bricks into clinkers, and then incorporate the fragments of them into solid homogeneous structures with good cement, at less than two-thirds the cost of brick work. I sincerely hope I may live to see the day when bricks will be discarded, and I trust that the New Zealanders, when they explore the ruins of London, may find it necessary to dig very deep down into the *debris* before they find any "genuine, sound, square, hard-burned stock-bricks," for the ceramic museums of the future. The days are past when the color of cements must ever be thrown in our teeth as a reproach. Mr. Lascelles has shown the possibility of so coloring Portland cement as to render it scarcely distinguishable from red brick or terra cotta, and the house he sent to the Paris Exhibition, designed by Mr. Norman Shaw, formed a new departure in concrete building. Mr. Lascelles is able to prepare mouldings and dressings in this material at a less cost than the same work in cut bricks or terra cotta. In point of natural color, selenitic cement, which is a warm buff, leaves little to be desired. Another direction in which cement concrete may be used with advantage is evidenced by the manufactures of Messrs. H. Sharp, Jones & Co., of Poole. This firm has succeeded in making excellent drain pipes of Portland cement concrete. The manufacture is a very interesting one, and as I have recently been permitted to examine the works, you will perhaps allow me briefly to describe the process. Cement of high quality is mixed with crushed pottery in the proportion of 1 of cement to about 3 of pottery. The concrete is made in small quantities in a special mixing machine, the materials being first turned over dry, then sprinkled with water from a fine rose and made into a very dry concrete. The mixture is next lifted into a hopper, which feeds it automatically and very gradually into the moulds. These are made as cylinders of sheet iron, the proper distance apart to form the thickness of the pipe, from 1 in. to 3 in., according to its diameter. This mould rotates slowly on a turn table, while an iron rammer worked up and down like a beetle, compresses the concrete into the mould as it falls from the hopper. When the pipe is full, it is wheeled away on a truck, mould and all, and stands for from 24 to 48 hours to set. When taken from the mould, the newly-made pipe is steeped

for a week in a bath of silica, to indurate it more effectually, by the ingenious process invented by Mr. Highton, and used by the Patent Victoria Stone Company. The pipe may remain in the bath for about a week, when it is removed and stacked in the open air for some months before it is sent out for use. The Victoria Stone Company, just mentioned, make excellent paving slabs of granite chips and Portland cement. These slabs appear to be very durable, and they are not so costly as common York paving. Mr. Drake has recently shown me some interesting specimens of the marble and granite mosaic work and concrete his company are now producing. I have only now, in conclusion, to express the hope that I may have succeeded in showing that "the use of cement" is a subject well worthy of the careful attention of the architect.

In the discussion which followed, the President (Mr. Ernest C. Lee), while expressing his sense of the great practical importance of the subject treated of by Mr. Redgrave, said he was no great admirer of the homogeneous monolithic houses, the erection of which had been advocated.

Mr. W. H. Lascelles (of Bunhill row) exhibited a number of specimens of his moulded and colored concrete work, and in response to an invitation from the chair, made a few remarks about them. One moulded or coffered slab which he produced was, he said, designed by a well-known architect, as part of a new method of getting ornamental though fireproof ceilings in rooms. Iron joists were embedded in concrete, and upon these concrete-covered joists the slabs were laid direct, leaving the joists and the under surfaces of the slabs to form the ceiling of the room below, the upper surfaces of the slabs forming the floor of the apartment above. This simple mode of fireproof flooring had received the approval of several architects of distinction. The objection that such floors would be too resonant or noisy when walked upon to allow of their coming into practical use had been falsified by facts. He had built some small houses with floors of that construction, and the tenants made no complaint of noise. Such upper rooms, it should be remembered, being bedrooms, would mostly be carpeted over on the portions walked on. He was now engaged (in connection with one of the companies who made it their business to erect dwellings for artisans) in seeing whether he could not devise a floor of that kind for such buildings which should be cheaper as well as better than floors of the ordinary kind. The fireproof qualities of the floor had been tested at the Croydon Exhibition of the Sanitary Congress, with conclusive results in their favor. A remarkable property of the concrete material of which these floors were made was that it would bear the driving of nails into it, not only without cracking but would hold them most tenaciously. So well recognized was this quality of the material becoming, that bricks or blocks of it were now used for building into interior walls, instead of wood blocks, for fixing the joiners' work to. The first discoverer of this kind of concrete was the late Mr. Matthew Allen, but it had been much improved upon from time to time, and it had now been found possible to impart to it a good and durable red color. It could be moulded to any form, and was hardly distinguishable from, though much cheaper than, the best cut brick-work.

Mr. Drake thought that the difficulty of giving concrete work a good aspect externally was now being solved. It had been very difficult to obtain reliable coloring matter for concrete work, and of late he had turned his attention to making the natural surface of the material sightly and even beautiful in itself. Many of the aggregates used, such as marble and granite chippings, were beautiful in themselves, and he had succeeded in making a concrete with a smooth and semi-polished surface, in which the pieces of marble and granite forming the aggregates were shown in their own colors, forming a sort of natural mosaic work. (A door in this material, made for the Theatre Royal, Manchester, was exhibited.) The same material was also capable of large and effective use in the shape of small slabs or tiles for flooring purposes.

Mr. J. S. Quilter, in proposing a vote of thanks to Mr. Redgrave for his paper, said the more experience he had of the use of Portland cement, the more reason did he see to use it more largely than ever, and he was glad to see that its use

was becoming common on the better class of building estates in the neighborhood of London. On an estate at Streatham (entirely a clay district) houses were being carried up of concrete made of Portland cement and of burnt clay ballast in the manner suggested by Mr. Redgrave.

THE PREVENTION OF FLOODS.

From "The Engineer."

We have repeatedly called attention to the need for beneficial interference with the principal rivers of England; and we are glad to find that a chance exists that steps will be taken to mitigate a growing evil. A very influential deputation was introduced by the Duke of Bedford to Mr. Dodson, the President of the Local Government Board. The object of the interview was to request the Government to bring in a bill for the better regulation of rivers. It is to be regretted that this was not quite so definitely stated as it might have been, but Mr. Dodson understood his visitors. He could make no promises for the Government as a whole, but for himself he assured the deputation that the views expressed by the various speakers, and the statements which they had made should be brought before his colleagues, and would no doubt "have the earnest consideration which the gravity of the subject and the importance and number of those interested make it deserving of at their hands." The style in which the promise is worded is open to criticism, but the matter is to the point, and the members of the deputation had no reason to be dissatisfied with it; yet we fear that a long time will yet elapse before anything of much value is really effected in a practical way to improve our rivers. The deputation, however, have done one good thing. They have at last clearly indicated the amount of pecuniary loss caused, we shall not say by floods, but by the absence of all attempt at regulating the great streams which are supposed to drain this country. In dealing with this aspect of the question they were necessarily brief, for Mr. Dodson's time is valuable; but enough was said to convince the most incredulous, we should think, that the prevention of floods is a matter not of local interest but of national importance. Mr. Magniac, M.P., speaking for Bedford and of the Ouse, said that in his own locality 10,000 acres had been flooded this summer. One farmer paid rent for land he had not seen for two years. Mr. Coote, of Huntingdon, drew a frightful picture, which we have reason to believe was in no whit exaggerated, of the suffering and loss caused in his district by floods. Mr. Sergeant urged that in eighteen miles of the Severn Valley £63,000 worth of food had been destroyed. In the county of Worcester one landowner had lost £4000 a year, and so on. No doubt the pecuniary loss must be counted by hundreds of thousands of pounds per annum, and the mischief does not end there; for, besides not a few deaths caused by drowning, healthy districts are rendered insalubrious; fever and ague are to be found where they ought to be utterly unknown, and the young and the aged are hurried out of the world by the combined effects of damp and bad drainage. Thus in Huntingdon the death rate has been doubled.

We have heard it urged that the floods are not worse now than they used to be, and that if they are it is because of exceptionally bad weather. It is well that this theory should be demolished as soon and as thoroughly as possible. There can be no doubt that subsoil drainage not only greatly augments the work thrown on rivers, as we have explained in our impression for Nov. 5th, but that it also does much to raise the beds of the rivers into which storm waters are discharged. The continuous operation of natural forces tends to fill up the bed of every river, each tributary bringing down its own contribution of detritus. The tendency of the river current is to deepen the bed by scour. In some cases these forces very fairly balance each other; but the moment man begins to

work the balance is overset. If on the one hand he dredges and straightens the stream, he augments the velocity of the current, and causes more scour. Then the tendency will be toward the natural excavation of the river bed. If, on the contrary, he drains the land over the area of the watershed supplying the river, then will the tendency to silt up become predominant, and the bed of the river will gradually rise. Mr. Magniac gave some admirable illustrations of this truth to Mr. Dodson. Every fresh flood brought something down the Ouse which stopped somewhere and caused an obstruction. Thus at Bedford a fallen willow tree had produced a sandbank. At particular places where the river used to be deep, it can now be crossed dryshod in summer. In English rivers the tendency to silting up is not—or rather was not before the days of extensive subsoil drainage—manifested to anything like the degree to which it is to be seen on the continents of Europe and America. The floods at Zegedin afford an illustration of what we mean. The melting snows in the Carpathians carry with them great quantities of silt, which gradually raises the level of river beds. The people dwelling on either bank, instead of dredging, make embankments to keep back the water, and as silting and embanking have gone on steadily for generations, the rivers now flow several feet above the level of the surrounding country. When a dam gives way, ruin and death on a frightful scale ensue. In process of time, unless proper precautions are adopted, such rivers as the Ouse will cease to have any proper beds, and will wander over the face of the country, finding an outlet to the sea where they can. All sluggish streams tend to form marshes, and this fact should never be forgotten.

In dealing with the regulation of rivers question, Parliament will do well to remember that the flood evil is a growing evil. Year after year matters will be worse and worse. The area flooded will be increased in dimensions. The quantity of land permanently submerged will be augmented. The waters will "come out" sooner in the year and will remain longer. Small local thunderstorms will produce local floods, and the pecuniary loss to the nation will grow larger and larger each year. It is essential, therefore, that Parliament should take the matter in hand without delay. It is not at first sight easy to see why it it has not been taken up long since; and this fact has been used as an argument against parliamentary interference. The evil, we have been told, is not really so great as it is said to be, or it would have been found intolerable long since. A little reflection will, however, suffice to prove that this is a specious and useless argument. It is a very serious matter, in the first place, to attempt the regulation of a large river on a comprehensive basis. None but highly trained and competent engineers can carry out such a work successfully. Again, the cost must be great; and last, and certainly not least, the determination of the legitimate incidence of the cost of the regulation works constitutes a complex and troublesome problem. Those living on high ground at each side of a river assert that the floods do not hurt them, and Jones cannot see why he should be taxed to prevent Robinson's farm being flooded, Jones the while willingly remaining blind to the fact that it is not the rain which falls on Robinson's farm which floods it, but that which fell on Smith's, Brown's and Jones', and a great many other farms standing at a higher level or lying further up the stream than Robinson's farm. We are not sanguine enough to expect that the tribe represented by Jones will ever be brought to see the propriety of paying anything for the help of the class represented by Robinson, and for this reason the whole matter must be dealt with on a very wide basis. The regulation of rivers must be regarded as the business of the nation, and not of individuals. As soon as the subject is brought before Parliament some person or persons who care nothing about floods will urge that Parliament cannot legislate on the subject because it knows nothing about it. Parliament will admit the truth of this statement, and then a select committee will be appointed, and scores of witnesses will be examined, and a year or two will pass and nothing will be done; and, finally, the committee will get all its ideas concerning floods and the way to prevent them jumbled up together, and we shall have a report which will not in

any way elevate the standard of Parliamentary knowledge, or enable Parliament to legislate on the subject with more prudence or skill than it possessed before the inquiry was carried out. The proper course to be pursued by the Government is to appoint a commission of three engineers of the highest standing and greatest skill in river regulation. These gentlemen will then visit and examine the principal river valleys of the kingdom, obtaining information on the spot, and in a very short time they will be able to answer one or two very simdle questions, which may be thus stated. Can the floods in the river be reduced by regulating its course? What is the area implicated in the production of the existing floods? What is the area now flooded every year? Is the *regime* of the river becoming better or worse? In general terms, about how much will the necessary works cost? Answers to all these questions could be obtained in less than three months by a competent commission of experts, aided by a sufficient staff, who would be on the spot to see for themselves, and who would be able to appreciate the statements made to them. The Government could then go to Parliament with something like a definite scheme. It could say, "this work can be done to advantage; it will cost so much; the money will not be wasted; it must be raised on such, and such, an area, and will represent so much in the pound sterling annual value of the land implicated." The cost of an investigation would not be one-fourth of that of a select committee, which could be called upon to hear counsel, and investigate the rights of every petty little mill owner on the river's brink. There can be no doubt that at the present time the interests involved in water rights and so on, are all mixed up in a deplorable muddle. Mr. Magniac, dwelling on this fact, cited the case of the town of Turvey in Bedfordshire: "The state of things," said Mr. Magniac to Mr. Dodson, "is frightful. The bed of the river belongs to one man, the right bank to a second, and the left bank to a third proprietor; and all the while the bed of the river in the proper sense has no practical existence." Under such conditions any measure must be sweeping if it is to be effectual. River beds should, indeed, be regarded not as the property of individuals, but of the nation; and if this be considered to be going too far, care should be taken that vested rights should not become vested wrongs to other men. A little mill weir may now cause the flooding of hundreds of acres of valuable land. Time was when the mill was, perhaps, worth more than the land, but the land has been reclaimed and improved, and is worth ten times as much as the mill. Why should not the millowner be paid a fair price and sent about his business? If Parliament is not prepared to deal with this matter with a strong hand, and do some injustice, that it may remove what is day by day approaching more and more nearly to the condition of an intolerable evil, then it would be better to leave the subject untouched. A grand opportunity is presented for useful legislation; but the opportunity will be entirely lost if Parliament is disposed to split hairs concerning the rights of millowners and certain other water-side proprietors.

COFFERDAMS IN FLOODED RIVERS.

By M. LANTEIRES.

From "Abstracts" of the Institution of Civil Engineers.

THE author describes the erection of masonry piers or coffer-dams for two bridges over the Garonne at Muret and at Cazères, during the time of the high floods of that river in 1875, when three out of four coffer-dams were carried away. The bed of the Garonne, throughout the greater part of its length, consists of a tufa, or clayey sandstone, composed of schistose sand agglomerated by an argilo-calcareous gangue. These coffer-dams were built in the ordinary way with wood piles 10 inches in diameter, driven for 19 to 31 inches into the tufa. In driving the piles the tufa was splintered and broken up,

so that the hold of the piles was very insufficient, and the buoyancy of the wood-work made it easy for the flood-stream to carry it away. In rebuilding the coffer-dams, wood piles were used only at the meeting of the ends of the longitudinal timbers or binders, the intervening panels of sheet-piling being supported by bar-iron piles 2.38 inches diameter clamped between the binders. The wood piles were 12 inches in diameter, provided with shoes with lance-like terminals 20 inches in length, driven into the tufa at the bottom of holes bored about 3 feet deep, with a 10 inch spiral augur. At about this depth boring was generally stopped by meeting a hard substratum, into which the pointed shoe only was driven. The bar-iron piles were driven about 6.5 feet into the tufa without materially breaking it. The piles were from 5.24 to 6.3 feet apart, and were 27 feet in length. The sheet-piling was 4 inches thick. two rows only of horizontal binders about 7.5 inches square being used. The double rows of piling of these dimensions were 5.24 feet apart, the interspace being filled in with tempered clay let down in blocks and well rammed. The dams so made, though light, were successfully used in completing the work. A statement of the cost of the dams in detail is given.—(*Annales des Travaux Publics.*)

THE QUANTITIES OF WATER IN GERMAN RIVERS.

From "Nature."

An attempt has recently been made by Herr Graeve (*Der Civil-Ingenieur*) to determine the amount of water in German rivers and its apportionment in different seasons, a question very important for navigation, and also of much scientific interest. His research comprehends the chief rivers of Germany, excluding the Danube, which begins to be navigable only outside of Germany, and including the Vistula and the Memel. He first calculated, from the mean heights of water, the quantities of water flowing out per second, and he adds a table in which the amount of outflow is shown in relation to the extent of the corresponding river territory. When the amount of outflow per 100 sq. km. of the region of precipitation is calculated the following values are obtained:—(1) the Rhine at Coblentz above the Moselle mouth delivers per 100 sq. km. of land 1.070 cub. m. of water in a second; (2) the Weser at Minden, 0.826 cub. m.; (3) the Elbe at Sorgau, 0.579; (4) the Elbe at Barby, 0.554; (5) the Oder at Steinau, 0.460; (6) the Oder below the Warta mouth, 0.413; (7) the Warta near its mouth, 0.344; (8) the Vistula at Montau Spitz, 0.538; (9) the Memel at Tilsit, 0.600.

From these numbers it appears (*a*) that the average outflow of different rivers, from equal portions of their territory, differs much more than is usually thought, for in the Middle Rhine it is about three times, in the Middle Weser two and a half times, and in the Middle Elbe, as also in the Lower Vistula and Memel, more than one and a half times as much as in the Lower Warta. On the whole, it decreases from the Rhine to the Warta, and from the latter increases again to the Memel. (*b*) In one and the same river the quantity from equal portions of land seems as a rule to decrease down stream. (*c*) All calculations of quantity of outflow in streams, based merely on extent of the region of precipitation, must, as a rule, give incorrect results.

It was important to try and determine the relations of the quantity of outflow to the rainfall of the corresponding regions, and Herr Graeve, doing so by a method which he describes, obtained the following percentage numbers, corresponding to the above series of rivers:—(1)=38.5 per cent.; (2)=37 p. c.; (3)=30 p. c.; (4)=28.5 p. c.; (5)=27.2 p. c.; (6)=21.4 p. c.; (7)=21 p. c.; (8)=29 p. c.; (9)=32.5 p. c.

From this the following conclusions (briefly) are drawn:

(*a*) The percentage proportion of the amount of outflow to the rainfall differs

very considerably in these several rivers, though far less than the amount of outflow from equally large regions of these rivers; hence the differences of the latter can be due only in part to differences in the rainfall.

(*b*) The percentage decreases from the Rhine to the Warta, and increases again from the latter to the Memel. In one and the same river a decrease is perceptible down the stream, at least so far as the phenomena in the Oder and the Elbe are general.

(*c*) Since in a mountainous region a greater part of the atmospheric precipitates is carried off by rivers than in the plain, the steady decrease in the percentage proportion of outflow to rainfall, in the direction from the Rhine to the Warta, must be primarily attributed to the increasing flatness of the region; so too must the decrease of the percentage down stream. The influence of more or less wood on the land could not be precisely determined.

(*d*) The marked increase of the percentage in the direction from the Warta to the Memel cannot be explained by the orographic conditions of the region of precipitation, because this region in the case of the Memel is not at all hilly, and in that of the Vistula only a little more hilly than that of the Warta, but since the amount of the evaporated part of atmospheric precipitates is considerably influenced by the mean temperature of the region of precipitation, and this in the region of the Vistula and the Memel is lower than in that of the Warta, the increase of percentage in question from the Warta to the Memel must mainly be attributed to climatic conditions.

(*e*) While the percentage in question must be chiefly governed by orographic and climatic conditions, there can be no doubt that other factors also act, *e. g.*, the relative amount of moisture in the air, which influences the degree of evaporation, and in general must decrease from the rainy Rhine region to the dry region of the Warta; further, the amount of plantation, which in the regions of the Vistula and Memel is larger than in those of all other German rivers; lastly, the nature of the ground, allowing more or less passage to the precipitates; the influence of all these factors, however, cannot be proved with the same certainty as the orographic and climatic conditions.

A comparison of the amounts of outflow in different years shows that in individual rivers more important differences occur than are generally supposed, that these differences in rivers of different character and unequal force are very different in amount, and that in the same river they decrease down stream.

With regard to the difference in amount of outflow in the various seasons and months, the following average values were obtained. The amount of outflow in winter (from the beginning of November to the end of April) is to that of summer, at the parts of the stream examined, in the Rhine as 1 : 0.922, in the Weser as 1 : 0.434, in the Elbe as 1 : 0.467, in the Oder as 1 : 0.525, and further down stream as 1 : 0.522, in the Vistula as 1 : 0.486, and in the Memel as 1 : 0.389. A better idea of the regularity of the quantities of outflow is given by the relations of these for the dryest and the wettest month of the year; in the case of the Rhine this ratio is 1 : 1.458, in the Weser 1 : 4, in the Elbe 1 : 5.238, in the Oder 1 : 4.5, and further down 1 : 3,68; in the Vistula 1 : 4.19, and in the Memel 1 : 4.51.

The causes of the difference in the ratio of the largest and least monthly amounts of outflow must chiefly be sought in the presence or absence of collecting basins, as also in the orographic and climatic conditions. In the Rhine all those factors combine which affect the regularity of outflow. It possesses in the Swiss lakes large reservoirs; its river region comprises mountains of various height, and plains, so that the melting of the snow must occur at very different times of the year. The Memel also possesses reservoirs in its marshes, and its region is perhaps better wooded than that of the other streams of Germany; but the long and hard winters cause an accumulation of large masses of ice and snow which melt suddenly and almost simultaneously in the whole region.

Herr Graeve takes up various other points, which have a practical bearing on navigation, but for these we must refer the reader to his memoir. He remarks, in concluding, on the desirability

of comparing the conditions of outflow of German rivers with corresponding data for other European rivers, though at present the scanty and incomplete character of the data at hand render such inquiry scarcely practicable.

A PERMANENT STANDARD CELL.

By MAJOR R. Y. ARMSTRONG, R.E.

From Papers of the Royal Engineer Institute.

THE following description of a very simple standard cell of nearly unlimited endurance, and not likely to be injured by accident, may be interesting to those who cannot conveniently procure the more accurate standards now made.

It can be made by a novice without difficulty, and gives, when used with an electrometer, results within one per cent. of the truth.

In two porcelain or earthenware chambers, separated from each other by a *non*-porous partition, are placed the zinc and copper elements respectively. A semi-saturated solution of sulphate of zinc is poured into the compartment containing the zinc element, and a saturated solution of sulphate of copper is poured into the other.

The cell may remain in this condition apparently for years without undergoing any change: it is merely necessary to add distilled water to the solutions from time to time, as their level falls through evaporation, and to prevent the sulphate of copper from creeping up the sides of the cell.

When it is desired to use the cell as a standard, a string of cotton or twine is dipped in water and used to connect the liquids, which are thus connected electrically, but do not mix for hours. At the conclusion of the experiment, the string is removed and thrown away and a fresh one used next day. .

After employing some of these cells for a couple of years no traces of copper could be detected in the zinc cell.

The electromotive force varies under conditions which I have not determined from 1.083 to 1.065 ohms; that is only 0.83 per cent. from the mean value of 1.074. It is unaffected by raising the temperature to boiling point; and I have not observed that action of light produces any alteration.

A number of these cells when first made up were within an extreme range of 1.069 to 1.077 ohms.

It is probably desirable to employ commercially pure metals and salts, although I have not found that cells prepared with the above precautions differ in any way from those made up with ordinary commercial materials.

As I have already stated, this is not in its present condition an accurate standard, but it is a very convenient one for work not requiring greater accuracy than can be obtained by its means, especially if it can be checked at starting by some recognized standard.

This cell may be used with a potentiometer, provided that a reflecting galvanometer be employed with a connecting key, and that the contacts be made as short as possible, until the resistances have been so adjusted that there will be no deflection of the galvanometer on a more prolonged contact being made.

The results obtained with a condenser are not very accurate, as even the current required to fill a capacity of about $\frac{1}{3}$ microfarad appears to lower the EMF of the cell at the moment abont 2%.

N. B.—From experiments made during the past two months I think that the value of 1.07 volts will not differ more than 0.5% from the correct value. The previous experiments were made with a zinc wire soldered to the zinc element and a copper wire to the copper element, and the variations made have been caused to some extent by damp at the junction of the copper lead with the permanent zinc wire; at any rate, since a copper wire was *soldered* to the zinc element the EMF has only varied from 1.065 to 1.075 volts. The mean value of which is 1.07 volts, which should be taken as the actual value.

SIGNALING BY MEANS OF SOUND.

By E. PRICE-EDWARDS

From the "Journal of the Society of Arts."

In a recent trial it was argued that the transmission of verbal sounds, *i. e.*, of the sounds produced by articulate speech, should properly be regarded as signaling, but in connection with the observations which I shall offer to you this evening, I prefer to accept the view of the learned counsel on the other side, and to avail myself of his retort to the effect that, although my remarks are in a sense transmitted to distant hearers in this room, yet it would be an obvious misapplication of terms to say I was signaling to those hearers. I think it necessary to make this preliminary observation, because it is beyond my purpose, on this occasion, to deal with those methods of conveying oral sounds which have been so marvelously developed during the last few years. The value to mankind of these astonishing discoveries cannot yet be fully apprehended. We are evidently on the threshold of great changes, as regards means of carrying messages; the steam locomotive, the penny post, even the telegraph system itself, are threatened by the possibility of other more simple and direct methods being brought into practical operation, by means of the telephone, the phonograph, the microphone, and last, but by no means least, the photophone, of which so brilliant a description was recently given in this room by its talented discoverer.

But these are not the instruments which minister to the practice of signaling, in the sense in which I desire to place it before you.

A signal is defined as a sign which has been agreed upon to give notice of some occurrence, command, or warning, to a person or persons at a distance. The necessity for such means of conveying intimations is too obvious to be dwelt upon. I need hardly recall to you the system of signaling by beacon fires, which was so extensively in use in early days; nor need I remind you that those crude methods of ancient times have, in the process of time, been generally superseded by simpler and more effective means. The splendid lighthouses on our coast, which convey guiding and warning signals to the mariner; the colored and other lights used for vessels at sea, and also for railway purposes; flashing signals, employed for communicating between H. M. ships at night, and for other purposes, are all suggestive of ancient practice, although more elaborate and perfect, and suited to modern requirements.

Flags, again, have for centuries been used as emblems and signals for the conveyance of messages across intervening spaces. For military purposes they continue to be used, and for service at sea they have been so effectively utilized that there now exists an international code, generally adopted by all maritime nations, which permits conversation to be carried on between ships of all countries, the combinations of eighteen flags and three pennants being the signals whereby messages pass between mariners who do not even understand each other's language.

The semaphore was once much used for military signaling, but it is now almost entirely employed in connection with the railway service.

For storm warnings, drum and cone shapes are hoisted at prominent points on the coast, to indicate the approach of bad weather.

And I may allude to the valuable invention of the heliograph, or sun-flashing mirror, which rendered such conspicuous service in the late wars in Afghanistan and South Africa, by which signals can be flashed across an intervening space of from 50 to 100 miles.

Finally, signals of distress are made on board ship by the firing of rockets, and by flames on the deck.

It will be observed that the examples of signaling to which I have alluded are those which appeal to the sense of sight only. Signals, being intended for

human purposes, are, of course, dependent upon human perceptions for their comprehension. Sight, as we have seen, is made available. I do not think any definite system has been developed by which signals can be transmitted through the medium of taste or touch; nor has science yet indicated any method of utilizing the sense of smell for the conveyance of definite messages, although, in the vincinity of foul places and decomposing refuse, odoriferous signals are generally wafted abroad, plainly indicating the presence of germ-laden gases, and silently bidding us beware.

But the necessity for transmitting signals has been found to exist at times when sight is unavailing, and then the sense of hearing naturally suggested itself as the perception which should be appealed to.

Thus we arrive at the branch of the subject which I have ventured to bring under the notice of the members of the Society of Arts this evening; and I think it proper to say, that in preparing this paper, I have sought rather to make it a record of facts than anything like a speculative inquiry, and have encouraged myself to hope that my efforts may possibly be the means of bringing to bear upon the subject the scientific and mechanical intelligence of many, in such an audience as this, and who may assist in the valuable work of developing the means of making sound signals fulfill their purposes with accuracy and precision.

The effective employment of sound signals appears to be chiefly dependent upon two factors, the facilities offered by the atmosphere as a vehicle of sound, and the human capacity for hearing and distinguishing sounds of different characters. It will, perhaps, be convenient to regard first these two points, and afterwards to deal with the application of sound signaling for various purposes, and the different kinds of instruments used to produce the sounds.

It is hardly necessary, before such an audience as this, to attempt an explanation of the general laws governing the propagation of sound; and, in the presence of so eminent an authority as the learned professor who has so highly honored my subject and myself by presiding this evening, to do so would show some temerity on my part. It is, nevertheless, necessary for me to put before you briefly various considerations relating to sound transmission, which have a direct bearing upon the matter in hand, but is only proper for me to observe that in this respect I must borrow the thunder of your learned chairman, and place before you results obtained through his patient investigation, judicial weighing of evidence amid conflicting theories, and unstinted expenditure of time and personal comfort.

The atmosphere is the vehicle for transmission of sound with which we are this evening concerned. Water is an excellent medium for sound traveling, and the possibilities which have from time to time been suggested in regard to it, require only the attention of inventive genius to bring them within the range of practical reality and utility. But as at present the atmosphere is the only medium which is practically available for the transmission of sound signals, it becomes important to know whether some conditions are more favorable than others for its passage.

It is evident that there are various influences which may be supposed, in one way or another, to affect the transmission of sound. Wind has always been known as a most powerful agent in intercepting and even diverting it. Fog, snow, and rain, have also been regarded by many as serious obstructions, while it has long been popularly consdered that a bright, warm, sunshiny day, with little or no wind, was exceptionally favorable for the traveling of sound. These views, it may be said, have grown up as the result of general expectation rather than of scientific observation; but the development of signaling by means of sound has necessitated a more exact inquiry, than has hitherto been made, into the general subject of sound transmission, and the result has been that some of the old theories have been considerably shaken, if not overthrown, while new ones have been set up.

In the years 1873 and 1874, an investigation was carried out, at the instance of the Trinity House, with the object of obtaining some definite information as to the relative merits of sound-producing instruments, and also of ascertaining how the propagation of sound was af-

fected by different meteorological phenomena. Professor Tyndall, as the scientific adviser of the Trinity House, conducted the investigation, aided by a Committee of the Elder Brethren, and some officers of the Corporation. The experiments were extended over a lengthened period, observations being made in all conditions of weather, and repeated over and over again, in order to eliminate error; and the information gained thereby is of the highest interest and importance.

The results are stated at length in the third edition of Dr. Tyndall's book on "Sound," but may be popularly summarized as follows: That neither rain, hail, snow, or fog, has any sensible power to obstruct sound. From this it is most satisfactory to know that, at those times when a sound signal might especially be of service, the sound is not likely to be obstructed in its passage. That the real obstructors of sound are—first, the wind; and, secondly, what Dr. Tyndall has named acoustic clouds. These clouds have nothing to do with ordinary clouds, fogs, or haze, and may arise from air currents differently heated, or from air currents differently saturated with vapor, and they often exist on days when the atmosphere is in a very transparent condition. The obstruction is caused by the sound, intercepted by the acoustic clouds, being wasted by repeated reflections. In short, it is now established that a bright clear day is not necessarily the best for hearing distant sounds, and that on a day of dense fog it is more than probable that no obstruction is offered to the passage of sounds.

I must not omit to mention that experiments of an elaborate nature, in respect to the propagation of sound in the atmosphere, have also been made under the auspices of the United States Lighthouse Board, with results mainly corroborating those obtained in the Trinity House trials. In one respect, however, the late Prefessor Henry, who was at the time Chairman of the United States Lighthouse Board, differed from Dr. Tyndall, viz., in regard to the theory of acoustic clouds, and their resultant aerial echoes. Professor Henry's explanation of the obstruction of sound in clear weather, and the echoes, is founded upon the asserted existence of upper and lower currents of air, the tilting up of the sound wave, and the reflection of the sounds from the surface of the sea, or the crests of the waves. From this last explanation, Professor Henry seems to have receded before his death. Into the details of this purely scientific controversy, it is not necessary to enter; but it may be stated, as a matter of fact, that observations at the South Foreland, and the explanations given of them by Professor Tyndall, have been, one and all, illustrated and confirmed by strict experiment.

One other point may appropriately be alluded to here, viz.: as to the nature of the sound which is most readily propagated through the air, and which, therefore, is most effective for signaling purposes. It appears that what Mr. Alexander Beazeley (who very ably treated this subject of coast fog-signals some years ago) has termed "effective sound range," is made up of two factors, viz., intensity and pitch. It is tolerably well established that initial intensity is the first thing needful, and initial intensity depends upon the actual force employed in creating the sound waves. With suitable apparatus, and an effective application of very high power, there is little doubt that sounds of overpowering loudness may be produced. But the effective range of sound appears to be also controlled by its musical pitch. The short waves of a very shrill or high-pitched sound may appear extremely powerful and effective to observors in the immediate vincinity, but their energy seems to be quickly dissipated, and the sound fails to be appreciated effectively at a distance. Again, the long undulations of a very low-pitched sound do not apparently often reach great distances. It may be that this kind of movement is more readily acted upon by opposing influences, such as reflection or diversion. But, for practical purposes, it seems that the pitch best adapted for signaling lies about the middle of the scale of sound. With sound, as with light, there are wave motions above the highest pitch intelligible to the human ear, and below the lowest sound audible, and it may be, that the nearer sounds approach the limits of human apprehension, so they tend to become less appreciable. In addition to this, it has been found that the atmos-

phere exercises a selective influence, and, within certain limits, will, under some conditions, favor the transmission of the shorter waves, or high-pitched note; while, at another time, it may be found that the longer waves of a low pitched note have the advantage.

Speaking generally, the range of sound seems to be attended with much uncertainty. It is popularly supposed that if a sound, at any one time, is heard ten or fifteen miles, it must necessarily be an exceedingly powerful sound. Now, this does not follow as a matter of course. The variability of the atmosphere will throw out any calculation made upon such an hypothesis. In the experiments at South Foreland, in calm, clear weather, one of the instruments was, on a certain day, heard at a distance of 16½ miles, but on another day, with apparently identical weather, the same instrument was heard at only 2½ miles distance. Obviously, it is no satisfactory test of a good signal that on one occasion it had a great range—sounds comparatively small and weak have at times been audible at long distances—and, therefore, I need not trouble you now with instances of this kind. The true test of a sound signal appears to be that it shall, under all conditions of weather, be uniformly effective at a short distance—say two miles.

I referred just now to what, perhaps, I may speak of as the sound spectrum, and to the limits of human capacity in regard to hearing sounds. Now, with the development of signaling by means of sound, I am not sure that the human capacity for hearing and distinguishing sounds of different kinds has received the consideration which it merits. Let it be granted that you have instruments capable of producing sounds of great power; let it also be granted that the signals appear to be distinctive and easy of comprehension, you will, I fear, still find very many people in the world, incapable of availing themselves of such signals, either by reason of whole or partial deafness, or inability to appreciate differences in sounds. Now, the question almost naturally asserts itself, cannot something be done to assist the ear, or, at any rate, the perception of sounds in the air. This seems to be the complementary side of the general question, to which but little attention has been given. In regard to visibility, you have telescopes and binocular glasses, by means of which a distant object can be brought more plainly into view. But nothing of any real value has been done to assist the hearing. The old-fashioned ear-trumpet for deaf people is little, if at all, improved. Some years ago, an effort was made in this direction by a gentleman from Glasgow, who devised what he termed a phonoscope. This instrument consisted of a sort of metal helmet for the head, with an opening like the bent cowl of a chimney, which could be directed towards any point required. This cowl was supposed to act as a sort of ingatherer of sounds, which were conveyed to the ears by two small tubes, each terminating in a button, intended to go just inside the ear. The faults of this apparatus were, first, its cumbrousness, and, secondly, the remarkable way in which all the ordinary small noises around were collected and magnified into large ones, which, combined with other sounds hitherto unheard, created a general uproar in the ears. The object this gentleman had in view deserved greater success than it obtained. He wished to assist the mariner in picking up and locating a distant sound; and, although his apparatus acted so well that it picked up noises of all kinds, and somewhat bewildered the sense of audition, yet I venture to say that if any one were to accomplish successfully what this gentleman so perseveringly attempted, a very great public benefit would be brought about. I do not mean to convey that what is specially wanted is an improved ear-trumpet for deaf persons, but rather, an instrument intended to aid people with fair hearing, or to render sounds, in some way, more easily perceptible. The late Professor Henry, of Washington, in carrying out his experiments, devised what he termed an artificial ear, by which the relative power of different sounds could be determined at short distances. This instrument consisted of an arrangement by which sand, on a stretched membrane, assumed certain definite forms, or was more or less agitated, in response to different sounds. As a phonometer, at short distances, this instrument appears to have been fairly effective, but it does not meet the want

which appears to me to exist. With the growing use of sound for various purposes, there is scope for inventive genius to produce a phonoscope, which shall be capable of assisting the listening ear in a manner analogous to that by which a telescope aids the seeing eye.

The following is a general statement of the chief purposes for which sound signals of different kinds are in practical operation:

1. *Railways.*—Whistles of locomotives and explosives as fog signals.

2. *At Sea.*—For merchant ships, the international regulations for preventing collisions at sea prescribe, as a compulsory requirement, that in fog, mist, or falling snow, whether by day or night, the signals described as follows, shall be used:

(*a.*) A steamship, under way, shall make, with her steam whistle, or other steam sound signal, at intervals of not more than two minutes, a prolonged blast.

(*b.*) A sailing ship, under way, shall make, with her fog-horn, at intervals of not more than two minutes, when on the starboard tack, one blast; when on the port tack, two blasts in succession; and when with the wind abaft the beam, three blasts in succession.

(*c.*) A steamship and a sailing ship, when not under way, shall, at intervals of not more than two minutes, ring the bell.

And, as an optional proceeding, that a steamship, under way, may indicate her course to any other ship which she has in sight, by the following signals on her steam whistle, viz.: one short blast to mean, "I am directing my course to starboard." Two short blasts to mean, "I am directing my course to port." Three short blasts to mean, "I am going full speed astern." A gun fired at intervals of about a minute is one of the authorized signals of distress at sea. In the Royal Navy the above regulations are also in force, but, in addition, Captain Colomb's system of sound-signaling is employed in fog, for the purpose of communicating between H. M. ships. Guns were formerly in use as fog signals, but are seldom if ever employed now.

3. *The Army.*—The only sound signals systematically employed appear to be those made with the bugle.

4. *Coast Fog Signals.*—By far the most important development of sound signals is in connection with the light-house and coast-marking service. The most powerful lights are unavailing at night if enshrouded with fog, and, by day, buoys, beacons, and other marks and signs of the sea, are then rendered useless. The necessity for sound signals to do duty at such times for the obscured lights and hidden sea-marks, has brought about the development of a system of coast fog signals, in which development, so far as the English coast is concerned, the Corporation which I have the honor to serve, aided by your distinguished chairman, Mr. James N. Douglass, the Trinity House engineer, and others, have had a large share. The Commissioners for Lighthouses in Scotland and Ireland, aided by their respective engineers, have also taken vigorous measures for guarding their coasts with fog signals when necessary. It is proper, however, to observe that the lighthouse authorities in the United States took up the matter practically before it engaged much consideration in this country, owing to the east coast of America being in an exceptional degree liable to the visitation of fog, by which the coasting traffic was seriously inconvenienced; and the necessity arose for something to be done whereby the difficulty might be obviated. The ready genius of the country was not long in coming to conclusions, and although some kinds of sound signals, such as bells, gongs, &c., were employed in Europe, the Americans first brought into use Brobdignagian trumpets, whistles, &c., to which I shall refer in due course.

We will now pass on to consider the different kinds of instruments employed in connection with the various purposes to which I have referred.

Bells.—Bells, from the earliest times, have been employed to convey intimations by means of sound. Their chief uses in olden times have been summed up in the following:

"Laudo Deum verum, plebem voco, congrego cherum,
Defunctos ploro, pestem fugo, festa decoro."

In these days churches have not a monopoly in regard to the use of bells. The town crier, the muffin seller, the railway porter, and many others signalize themselves by the ringing of bells

With these, however, we are not concerned, unless we may express an opinion that in some of these cases it would be an addition to the public comfort if they were suppressed.

The present regulations for preventing collisions at sea require that, in fog, mist or falling snow, "a steamship and a sailing ship, when not under way, shall, at intervals of not more than two minutes, ring the bell." These regulations are international, but the Turkish Government have objected to the use of bells as fog signals on board Turkish vessels, on the ground that it is against their religion to use bells on board ship; and, therefore, in all cases where the regulations require a bell to be used, a drum will be substituted on board Turkish vessels.

As warning signals, bells have been employed from a very early date. It is impossible to say when, or where, the first bell was put up to assist mariners; but we may quote the often-narrated tradition, handed down by an old writer, respecting the Bell Rock:

"By east of the Isle of May, twelve miles from all land, in the German Ocean, lyes a great hidden rock, called Inch Cape, very dangerous for navigators, because it overflowed every tide. It is reported in old times upon the saide rock there was a bell fixed upon a tree or timber, which rang continually, being moved by the sea, giving notice to the saylers of the danger. This bell or clocke, was put there and maintained by the Abbot of Aberbrothock; and, being taken down by a sea pirate a yeare thereafter he perished upon the same rock, with ship and goodes, in the righteous judgment of God."

The story, it is true, is only supported by tradition, but it serves to show that the notion of marking a hidden danger by a sounding bell was certainly in existence—if not practically applied—at a very early period. We know it was practically applied at Poolbeg, in Ireland, in 1811, and at the Bell Rock, in Scotland, in 1812; and we also know that, up to the year 1860, bells were established, to be sounded in foggy weather, at many other lighthouses on the coasts of Great Brrtain and Ireland, and of France, the United States, and other countries, many of which continue to be sounded at the present day. These bells vary in weight from 3 cwt. to 45 cwt., and are generally struck by means of clock-work. In no case does the bell itself move, the clapper or clappers, alone being actuated by the machinery. It is well known that the sound of a bell is curiously fluctuating. In the open country or at sea, in the neighborhood of church bells, the sound may be heard rising and falling, the peal swelling out as if close at hand—now fading into the thinnest sound, as if retreating far, far away. These effects are familiar to most people, and in themselves are really beautiful; but they come into play injuriously when the sound is wanted to be evenly distributed over a certain area. The truth probably is, that the vibrations from the largest bell are not of sufficient intensity to yield a sound capable of overcoming opposing influences, even of a slight nature. The sound produced in the immediate vicinity of the bell seems, no doubt, exceedingly powerful, the greatest energy of vibration being there exerted; but, at moderately long distances, this apparent energy is dissipated, and the bell ceases to be of use. It will be easily understood that little dependence can be placed upon bells as trustworthy sound signals for long distances. The effective sound range of the largest bell is at all times very doubtful; the wind may carry it to a distance even of 10 or 12 miles, but against the wind it may be inaudible at less than a quarter of a mile.

In one form the bell continues to be serviceably employed, viz., when fixed on the top of a large buoy, with four hanging clappers around the outside of the bell, which alternately strike the bell as the buoy is moved from side to side by the action of the waves. An incessant tolling is thus kept up; and at night, or in foggy weather, the signal is most useful to mark the turning points at the entrances to important ports, and at other places where the navigation is intricate, or to mark isolated dangers. The number of bell buoys round the British coast is considerable.

Gongs.—The next kind of sound producer we have to notice is the gong. To most of us, probably, the gong has an inviting sound, that is, as used for signaling purposes in our households. This instrument has been appropriated

for use on board the light vessels round the coasts, owing, probably, to its peculiar, distinctive sound. The gongs used in the Trinity House service are about two feet in diameter, of Chinese make, and cost about £4 each. They are struck with a stick with a padded head, the strokes being very short, and delivered in quick succession, so as to bring up the gong into a vigorous state of vibration. The sound is undoubtedly distinctive, and serviceable at very short distances; but, like the sound of a bell, is soon dissipated after leaving the immediate vicinity of the instrument. Passing vessels may approach nearer to a lightship than to a rocky coast marked by a lighthouse; therefore, a sound with only a short range may oftentimes be of great service. In many lightships, however, the gong as a fog-signal is now superseded by instruments of very much greater power.

Guns and Explosive Signals.—Guns are used for various purposes in connection with signaling. "The minute gun at sea," indicates that some vessel is in distress, and that assistance is required. This is one of the authorized distress signals. On board H.M. ships, guns have been employed for signaling in foggy weather, in accordance with an arranged code; and for salutes and other announcements, they are used at military depots and elsewhere. But their chief service has been as warning signals on headlands and dangerous points on a coast, to assist the mariner in foggy weather. The necessity for distinctiveness in the use of sound signals, and the loudness of the report yielded by the discharge of cannon, led to the adoption of this form of sound producer.

There is no doubt that these gun signals have been of the greatest value. Many and many a time the warning gun has been heard by the bewildered seaman in time to enable him to alter his course, and probably save his vessel. Formerly the guns were fired every fifteen minutes, but recently the interval has been altered to ten minutes. It would be difficult for two men to clean, load, and fire, for a lengthened period—say even twelve hours—with less intervals than ten minutes between each discharge.

The piece of ordnance ordinarily employed was the old long 18-pounder, with a 3-lb. charge of powder: but in the Trinity House experiments at the South Foreland, it was found that a short gun, the 24-lb. howitzer, gave a better sound than the long 18-pounder. Professor Tyndall thus sums up his opinion of the gun as a fog signal:

"The duration of the sound is so short, that, unless the observer is prepared beforehand, the sound, through lack of attention, rather than through its own powerlessness, is liable to be unheard. Its liability to be quenched by a local sound is so great, that it is sometimes obliterated by a puff of wind taking possession of the ears at the time of its arrival. Its liability to be quenched by an opposing wind, so as to be practically useless at a very short distance to windward, is very remarkable."

Professor Tyndall continues: "Still, notwithstanding these drawbacks, I think the gun is entitled to rank as a first-class signal."

In 1874–76, some experiments were made at Woolwich Arsenal, with the view of reducing the labor of firing, so as to enable two men to fire at more frequent intervals, and also to produce, if possible, a more effective report than had been obtained by discharges from guns of ordinary pattern. Colonel Eardley Maitland, of the Royal Gun Factories, Woolwich Arsenal, devised a form of gun, breech-loading, with six chambers, similar, in some respects, to a revolver, and with a parabolic mouthpiece fitted to the muzzle. The experiments gave promise that this fog signal gun would prove a success, and ultimately it was conveyed to the North Stack, near Holyhead, in order that it might have a practical trial. To reach the station, it was necessary to cross very bad mountain roads, and the gun received a severe jolting, and probably jarring, for it broke down shortly after being used. No further attempt was subsequently made to repair the damaged gun, nor to manufacture another, owing to the attention of the Trinity House being then diverted to gun cotton as an explosive sound producer. It should also be mentioned that, in the trials at Woolwich, one experiment was devoted to testing the comparative advantages of the various

kinds of service powder for noise-making purposes. The powders tested were: 1. F. G. (fine grain). 2. L. G. (large grain). 3. R. L. G. (rifle large grain). 4. P. (pebble). In point of effectiveness in sound producing, the result of the trial placed the powders exactly in the order in which I named them; the fine grain, or most rapidly burning powder, giving indisputably the loudest sound; while the report of the slowly burning pebble powder was the weakest of all. The 80 and 100 ton guns, fired with charges of 300 and 400 lbs. of pebble powder, do not make anything like so terrible a noise as the enormous charge would lead one to expect. The sound seems to lack intensity; and, in comparison with the sharp smack of the detonation of gun cotton, or of a much smaller charge of more rapidly burning powder, appears to be more of a prolonged and somewhat soft roar.

While upon the subject of guns, I must not omit to refer to the very ingenious invention of the gas gun by Mr. J. R. Wigham, of Dublin, the advantages claimed for which are that, where a supply of gas is available, the apparatus is very easily applied, and that, the gun can be loaded and fired at a considerable distance from the point of explosion. The gun consists merely of a tube about 18 inches bore and 12 feet long, placed at the point where the signal is required to be made, and connected with a gas main or gas holder, by iron piping. The gun is loaded with an explosive mixture of gas and atmospheric air, by turning on a cock simply, and is fired by a light applied by percussion or otherwise to the shore end of the tube, the explosion taking place at the mouth of the gun almost immediately. Mr. Wigham states that a gas gun may be fixed at the water's edge, or on a rock in the sea, at half a mile from the loading and firing station. The idea, which is certainly one of originality, was conceived by Mr. Wigham when he was engaged in connection with the application of gas to the lighthouse at Howth Bailey, and his experiments at that station have met with a very encouraging amount of success, but the system is not yet in practical operation as a fog signal.

In 1874, the Trinity House obtained the consent of the War Department to some experiments being made at the Royal Arsenal, with the object of ascertaining the value of the sound produced by the explosion of varying quantities of gun cotton. The explosion of gun cotton takes place so instantaneously, that an exceedingly sudden and sharp blow is given to the surrounding air, whereby a sound wave of great initial intensity is generated. A number of comparative trials were made at Woolwich and elsewhere, in which the superiority of gun cotton over gunpowder was incontestably demonstrated. It was found that charges of gun cotton, however fired, yielded reports louder at all ranges than equal charges of gunpowder; and further experiments proved that the detonation of half a pound of gun cotton gave a result at least equal to that produced by the firing of a 3-lb. charge of gunpowder. During these experiments, the various charges of gun cotton had been merely suspended from a horizontal bar, or in the focus of a large parabolic reflector, and fired by means of electricity. To explode gun cotton, it is necessary to employ a detonator, consisting of a small cylindrical copper case, resembling an elongated percussion cap, containing a certain quantity of fulminate of mercury. This detonator is inserted in the heart of the portion of gun cotton to be exploded, and an attachment is then made with one wire, connected with a small electric machine, and with another attached to a conducting plate embedded in the earth. On turning the handle of the machine, a current is induced sufficiently strong to generate a spark at the connection of the wires with the detonator, which, coming in contact with the fulminate of mercury, immediately explodes it, and instantaneously the explosion is communicated to the gun cotton. If gun cotton in a wet state is used, it is necessary to have a small plug or primer of gun cotton, into which the detonator is inserted. Four processes then take place, viz: 1. Generation of electric spark. 2. Ignition of detonator. 3. Communication of explosion to dry primer. 4. Communication of explosion of dry primer to the wet portion. The entire operation is, however, perceptible to the human sense as one explosion only. It will be readily un-

derstood that to discharge gun cotton in this way entailed some little expenditure of time and trouble, and might prove inconvenient, if required to be repeated every ten minutes for many hours during fog.

But it being clearly demonstrated that the explosion of gun cotton gave a very effective sound, a project emanated from the Deputy Master of the Trinity House (Admiral Sir Richard Collinson, K. C. B.), for making a rocket serviceable for carrying a charge of gun cotton up to a certain height, and then causing it to explode. This project was, with the aid of Mr. Brock, the well-known pyrotechnist, and, subsequently, Mr. Mackie, and the officers of the Woolwich Arsenal, after numerous experiments, made a practical success; and now, at five stations on our coasts, we have sound rockets, either substituted for guns previously used, or established *de novo* for signaling in foggy weather.

The following description of the rocket now used is given in the instructions issued to the fog-signal attendants at Flamborough-head, where sound rockets have been in use since January, 1878. The explosive used is a slight modification of gun cotton, called tonite, which is said to be cheaper than ordinary gun cotton, and as effective for producing a loud report.

DESCRIPTION OF ROCKETS.

For purposes of safety, the rocket is supplied, and is to be kept, in three parts, viz.:

(1.) *The Rocket.*—This is a case charged with the ordinary rocket composition, and is intended merely to carry up the explosive charge to the required height, and then to ignite the detonator which is to explode the tonite.

(2.) *The Detonator.*—This is an enlarged percussion-cap, filled with fulminate. Its duty is to cause an explosion to take place in the heart of the tonite charge, whereby that charge is exploded. The detonator is ignited by the burning of the rocket composition.

(3.) *The Tonite Cartridge.*—This is the explosive which produces the report, and which, with the detonator placed inside it, is to be fitted in the head of the rocket, when immediately required for use.

The fitting together of the three parts can be accomplished in less than a minute; the rocket is then lighted by applying an ordinary fusee to a piece of Bickford fuse, communicating with the rocket composition. The whole operation occupies less than two minutes. The cost of the rocket is about 1*s.* 5*d.*, whereas each discharge of the gun costs 2*s.*; and in foggy weather a rocket is sent up every ten minutes. The advantages gained by the introduction of the sound rocket are indisputable, in one particular more especially.

It frequently happens that the sound of a signal intended to be spread over an arc of, say, 180 degrees to seaward, is obstructed, or deflected, by intervening obstacles, so as to cause uncertain parts of the arc to be immersed in sound shadow, into which the sound penetrates with very feeble effect, and often not at all. This difficulty the rocket has surmounted most successfully.

The explosive charge is carried up to the height of about 600 feet, and is there caused to explode in free air. From the height at which the explosion takes place, the direct sound is sent downwards into places which would be completely hidden from the level at which a gun could be fired, and which would seldom be reached by the sound of its discharge. At Flamborough Head, the gun was placed on the extreme edge of the point, the cliffs being about 100 feet high. But in Bridlington Bay, at a very short distance to the south-westward, the gun was invisible at the sea level, on account of intervening faces and edges of the cliffs. A practical trial of the rocket *versus* the gun at this station clearly showed the value of the former. One man walked along the edge of the cliff, keeping the gun in sight, and several observers were below on the rocks at the foot of the cliff, it being low water at the time. It had been arranged that, upon intimation from the observers below, the man above should signal to the people at the gun station to fire, first a rocket, then a gun. At a quarter of a mile from the point, with a light wind against the sound, the first experiment was made. The rocket gave a loud and sharp report, the gun a dull, heavy thud. At half a mile the rocket was very loud, the gun very faint. At 1¼

mile the rocket was loud and distinct, the gun heard only by two observers, and then only with the most strained attention. The fact of the explosion of the rocket having been visible and audible on each occasion, shows that it was clear of the obstructions which quenched the sound of the gun, and hid its discharge from sight. It should also be mentioned that the charge of the gun is 3 lbs. of powder, and that the explosive charge of the rocket consisted of 4 oz. of cotton powder.

The sound rocket is now in use at Flamborough Head, at Lundy Island, the Smalls Rock, in St. George's Channel, at Heligoland, and at the Tuskar Rock, on the south-east coast of Ireland. The system offers the means of placing an effective fog signal at a rock lighthouse station, where limited space and accommodation would prevent the establishment of a gun, or signal requiring furnace and machinery.

The development of explosive coast fog signals has not gone beyond this point. Gun cotton and cotton powder (or tonite) may be handled and stored with quite as much safety as gunpowder; in fact, they are really less dangerous; but it has not yet been shown that other explosive compounds, such as dynamite, lithofracteur, blasting gelatine, or any other nitro-glycerine mixture, can be made practically serviceable. Some freeze at a temperature a little above 40° Fahr., and others do not lend themselves to manipulation, and to safe storing for lengthened periods. There is, however, every probability that further advances will be made.

One other form in which explosive signals are now used may here be mentioned. I have alluded to the gun fired at intervals of about a minute being the authorized signal of distress for ships at sea. Mr. Gardiner, of the Cotton Powder Company, has sent me particulars of a kind of signal which may be fired more easily, expeditiously, and effectively than the gun, thereby obviating loading every minute, an important consideration with a vessel in distress. This consists in a small charge of tonite made up in a sort of cartridge. When required to be used, one of these cartridges is dropped into a socket, and by pulling a lanyard attached to a friction tube, a small quantity of powder at the base of the signal is ignited, which blows the charge up into the air about 600 feet, where it explodes. At the moment of explosion some brilliant stars are also shot out, and thus the signal represents either a gun or a rocket, both distress signals. I am informed that many vessels have been supplied with these rocket signals, that their effectiveness is undoubted, and that the Board of Trade have sanctioned their use in lieu of either guns or rockets.

One further application of explosives requires attention, one probably more familiar than agreeable to most of us. I allude to the use of exploding signals on railway lines, to convey signals to engine-drivers and guards in foggy weather. and to do duty for the semaphores and colored light signals when they are obscured. The system appears to be, that a signalman, furnished with a supply of detonators, places himself near to the signal-box or semaphore in connection with which he works, and uses the detonators to stop a train, if the line is blocked by the fixed signal. The detonator consists of a small quantity of coarse gunpowder, tightly bound up with three percussion caps; it is fixed on the rail with lead clamps, and is exploded by the wheel of the engine going over it. The system is said to be fairly effective; but it is probable that the British public generally would not indorse that opinion, for most people are fully aware of the annoying delays involved by the system, and certainly do not relish the sudden explosions to which they are treated, while chafing under enforced detention in the train. There seems to be plenty of room for improvement: the system is cumbrous, and admittedly expensive; and we may well hope that a more effective and less objectionable method of signaling in fog may be devised for our railways.

Whistles.—The next instrument which claims our notice is the whistle. We will first regard it in connection with coast fog signals. For this purpose, whistles, whether operated by steam or compressed air, do not appear to have found so much favor in this country as in the United States and Canada; indeed, with the exception of one station in the Clyde, where two small whistles, sounding dif-

ferent notes, are in operation, there are no fog-signal whistles on our coasts. In the United States they have been employed at various points since the year 1851. The first was set up by Mr. C. L. Daboll, at Beaver Tail Point. In Canada, also, whistles have been in use for some time, the type adopted being that invented by Mr. Robert Foulis, of St. John's N. B., and known as the Vernon-Smith whistle; and in this country Mr. W. H. Bailey, of Salford, Manchester, has given much attention to the manufacture of whistles suitable for sound signaling. Steam whistles are simple enough in their arrangements, requiring only a boiler for generating steam, and a simple mechanical arrangement for opening a valve for the periodic passage of the steam to sound the whistle.

For air whistles, it is necessary to have some motive power to compress air, and also some mechanical arrangement to regulate the admission of the compressed air to sound the whistle.

In the Trinity House experiments of 1873–4, it was shown that the sound of the most powerful whistles, whether blown with steam or air, was generally inferior to the sound yielded by other instruments, and, consequently, no steps have been taken to extend their use in this country. Various reports have been circulated as to the great distance at which whistles have been heard on the American and Canadian coasts, but no such results as those claimed were obtained in the very careful trials, made with both American and Canadian whistles, at the South Foreland, in 1873.

The sounding of a whistle is caused by the vibration of the column of air contained within the bell or dome, the vibration being set up by the impact of a current of steam, or air, at a high pressure. It is probable that the metal of the bell is likewise set in vibration, and gives to the sound its *timbre*, or quality. It is to be noted that the energy so excited expends its chief force in the immediate vicinity of its source, and may be, therefore, regarded as to some extent wasted. The sound of the whistle, moreover, is diffused equally on all sides. These characteristics, to some extent, explain the impotency of the sound to penetrate to great distances. Difference in pitch is obtained by altering the distance between the steam orifice and rim of the dome; when brought close to each other—say within half an inch—the sound produced is very shrill, but it becomes deeper as the space between the rim and the steam or air orifice is increased.

The most recent adaptation of the whistle, as a fog signal, is shown in an automatic signal buoy, devised by Mr. J. M. Courtenay, of New York, by which a powerful whistle, fixed at the top of a buoy, is sounded automatically by the action of the sea. The apparatus consists of a buoy, 12 feet in diameter, with a tube 33 inches in diameter, and 32 feet in length, passing vertically through the center, and descending below the bottom of the buoy to a depth of about 20 feet, the object of this length of tube being to reach a depth where the water is not subject to wave agitation. The bottom of the tube is open, and freely admits a column of water, which is maintained at a constant level, and is not affected by the external superficial wave motion. The buoy, however, to which the tube is fixed, moves with the surface undulations of the water, and, of course, carries the tube up and down with it, thus establishing a piston and cylinder movement, the column of water in the tube forming a piston, and the tube itself being a moving cylinder, the weight of the buoy and the tube exercising a considerable pressure. By means of the motive power so established, air, which is admitted by stop valves into that part of the tube which is above the level of the water, is compressed and forced through a pipe $2\frac{1}{2}$ inches in diameter, communicating with and sounding the whistle at the top.

One of these buoys has been practically tried off the Goodwin Sands for some months, and has proved a success; two more are about to be placed at other points. On the coasts of the United States, France, and Germany, they have also been in successful operation for several months.

Whistles are supposed to be the best medium for making signals by sound on board steamships. The regulations, which I have previously quoted, specify the whistle for steamers; but it is necessary that precaution should be taken to en-

sure the whistles giving effective sounds. Many that I listened to appear to me to be dismal failures, more especially when first sounded, for frequently the condensed steam causes so much water in the pipe, that when a sound signal is required to be made in a hurry, only a rush of water comes through, without any effective sound.

On board the *Duke of Leinster* steamship, running between Glasgow and Dublin, a novel form of whistle, consisting of an organ pipe fitted on to the steam pipe, is said to give very superior results. It is said that it does not get choked like ordinary whistles; and that the sound emitted is loud and resonant, without the shrill disquieting tone of many whistles. This instrument is patented by Messrs. Hannan & Buchanan, of Glasgow.

With regard to the use of whistles on locomotive engines, I have endeavored to ascertain from sundry gentlemen connected with railway engineering (to whom I beg to offer my best thanks for their courtesy in replying to my inquiries), whether this kind of signal is the best for the purposes required, and from the replies I gather that the feeling is, "Well, it might be better, but it just answers." It does not appear that much is known by railway engineers about the construction or shape of whistles, and they seem to share the popular notion that the shriller the sound the more effective it is. Perhaps I may here venture, in the general interests of the traveling public, to utter a protest against the inconsiderate and often unnecessary manner in which whistles are sounded in the great railway stations of this country, and London in particular. I think it probable that this meeting will sympathize with me when I say that, in these days of nervous susceptibility, and when so many thousands of people travel daily by rail, something ought to be done by the railway authorities to abate the nuisance of unnecessary whistling, and certainly to put down the sudden, shrill, ear-piercing screeches, which make a strong man's nervous system tingle again, and which echo from roof, wall, and ground in reverberating shrieks. There is enough hubbub and racket at all stations, caused by the bustle of travelers, the arrival and departure of trains, the shouting and banging of doors by porters; and though all this may be called exhilirating, yet the addition of whistle screeches is too much to impose upon an enduring public. Drivers and stokers, with their deadened perceptions, are probably not aware of the real pain they often inflict on many persons by their thoughtless use of the whistle. If sound signals are so necessary, let them be low, soft sounds, or a full-toned bell. Such as are used on locomotives in the United States would be a great relief.

Fog Horns.—The next class of instruments to which reference should be made is the horn, or trumpet, in which air or steam pressure is employed to set in vibration a metallic reed or tongue, which vibration is communicated to air inside the trumpet, and also to the molecules of the metal of which the trumpet, or horn, is formed.

Mr. C. L. Daboll, of the United States, to whom reference has been previously made, introduced, in 1851, an instrument of this kind to the notice of the United States' Lighthouse Board, and a trial was made at Beaver Tail Point, Rhode Island. This instrument was sounded with air condensed by two air pumps, worked by a horse, the compressed air being stored in a receiver, and the trumpet sounded at a pressure of about 40 lbs. to the square inch. Ultimately, Mr. Daboll employed Ericcson's caloric engine as the motive power for condensing the air, and an automatic arrangement for regulating the blasts, and in 1862, he introduced his improved signal to the notice of the Trinity House Corporation, who gave it a practical trial at Dungeness. The results being very satisfactory, the Corporation placed other instruments of the same kind at several places round the coast, and one was fitted up on board the Newark light-ship. The experiments at South Foreland showed such instruments to be, under some conditions, very efficient, but they suffered from several disadvantages, which have led probably to their disuse of late years. I have alluded to the fact of some of the initial power being wasted in the case of whistles, by the metal of the dome, or bell, being set in vibration; this occurs to a greater extent with the huge brass trumpets which have generally been associated with reeds. In a paper read

before the Royal United Service Institution, in May, 1875, Admiral Sir Richard Collinson, in speaking of these horns, says, that "there are objections to the trumpet being made of brass, and also to the necessity which exists for tuning the reed in unison with the fundamental note of the trumpet." Sir Richard goes on to remark, "the use of a trumpet consists chiefly in concentrating the sound into a beam, and thus causing it to be projected through the air with greater force in any required direction. The brass trumpet, no doubt, does this to a certain extent; but as the molecules of the metal are also set in vibration, sound waves appear to be generated from all parts of the external surface of the trumpet, so that, although a very loud sound may be produced in the immediate neighborhood of the instrument, it is open to doubt whether that sound is transmitted with force to any great distance, its strength being, so to speak, dissipated in the space close to its source." The local noise occasioned by the vibration of the trumpet would be intolerable for any length of time. At the present time there are very few reed instruments with brass trumpets in operation, many of those originally established having been superseded by the siren, an instrument of which I shall speak presently. In connection with the development of reed horns very much is due to Professor F. H. Holmes, whose energy in connection with the electric light is well known. Under his immediate superintendence and advice two reed horns, sounded directly by steam, were fitted on board two light vessels sent out to China, and have worked very satisfactorily.

Reed horns are also used on board ship, chiefly sailing vessels, in compliance with the compulsory fog signals, and the optional sound signals, in connection with the "rule of the road" at sea. The horns now exhibited are lent for this evening by Mr. Nathaniel J. Holmes, of Holmes' Marine Life Protection Association (Limited). They are said to be very effective, but in a seaway, with the vessel rolling heavily, the seaman has some difficulty in working the instruments. It is air pressure which sets this reed in vibration, and produces the sound. In some trials recently made by the German Admiralty, these horns held a commanding position.

Recently, there has been brought into this country, from the United States, an apparatus known as Barker's marine safety signal, intended for use on board ship, to make sound signals. The apparatus has many merits, one of which is its simplicity in working; the second is that every signal is sounded automatically when once set; and a third is that, with the horn attached, it gives a very good sound. Compressed air is employed at a pressure of 6 lbs. to the square inch, and the sounding principle is a reed for the horn; but the inventor says, it can be equally well connected with the steamer's own whistle. The main object of the inventor appears to be to bring into use a short code of compass signals, by means of which vessels can indicate to one another their respective courses, the signal system consisting of eight combinations of long and short sounds. But it may be observed that the adoption of his code would make it necessary for the law to be altered, there being no permission or obligation to employ such signals in the rules now in force. And, again, the principle of long and short sounds which has been adopted, does not commend itself for service at a moment when there is no time to lose in deciphering the meaning of a sound signal from an approaching vessel. Captain Barker, however, has evidently had these considerations in his mind, for, in his descriptive pamphlet, he remarks that, though numbers of practical seamen consider the suggested code to be the simplest and best as yet brought forward, its adoption is by no means a *sine qua non*, since the machine can, with equal facility, blow any code which may be decided on. Captain Barker would probably do well to adapt his machine to sound only those signals provided for in the regulations.

Sirens.—We now come to the instrument which has been authoritatively described as "beyond question the most powerful fog signal which has hitherto been tried in England." In 1872, a committee from the Trinity House, who went to the United States, witnessed the performance of an apparatus known as the siren, and patented by Messrs. Brown, of Progress Works, New York, and in

the experiments at the South Foreland one of these instruments was sent over to be tried.

The instrument sent from America could be sounded either with steam or compressed air, made to pass through a fixed flat disc, fitted into the throat of a long trumpet, connected with the steam or air pipe. This disc has twelve radial slits, and beyond it is a rotating disc, with twelve similar slits, the rotation being effected by separate mechanism. Imagine, then, the pressure of steam or air to be on, with one disc fixed, and the other rotating; it will be understood that the slits in each frequently coincide—in fact the twelve silts in one revolution coincide twelve times, and at each coincidence a puff of steam or air, at great pressure, escapes through into the trumpet. It is the rapid succession of these puffs which form the sound of the siren. The disc is rotated so as to make 2,400 rotations in a minute; and as there are twelve coincidences in a revolution, it follows that the number of puffs passing through in a minute would be $2,400 \times 12 = 28,800$.

It can readily be understood that a sound of surpassing power is thus generated, and as the vibrations produced are not taken up by the cast-iron trumpet, the sound issues from the mouth in a condensed beam of great intensity.

It is not of importance to record the longest distances at which the siren has been heard, the sound-range under different atmospherical conditions being so exceedingly variable; but in regard to its superiority over other instruments, we may say that, under meteorological conditions unfavorable to the transmission of sound, the voice of the siren had a greater range than that of any other sound-producer; and that, when local noises—such as those of wind in the ears, rattling of rigging, breaking waves, shore surf, paddle-wheels, and the working of engines—have to be contended with, "its density, quality, pitch, and penetration, render it dominant over such noises after all other signal soudns have succumbed." It is obvious that this power to overcome obstructions is the true test of the value of a sound signal, and it is not surprising that the experience of the siren at the South Foreland should have led to the extensive adoption of this form of fog signal on the coast of Great Britian. Since 1874, no less than 22 sirens have been placed at the most salient lighthouse stations on our coast, and 16 on board lightships, moored in positions where a guiding signal is of the greatest service to the passing navigation. It should be added that, in the experiments, steam alone was used for sounding the siren; but the instruments now in operation on our coasts are sounded with compressed air, the motive power being caloric engines of greatly improved design and construction, examples of which are in exclusive use at the Lizard, both for the electric lights and the fog signal. Steam is not available at many lighthouse stations, owing to a scarcity of fresh water; and the caloric engine, which also rotates the siren disc, is regarded as safer and more economical in working than a high pressure steam boiler, and is independent of water supply. In America, Canada, and some other countries, steam has been employed with considerable success.

At Howth Bailey, a gas-engine is employed as a motor for compressing air for the siren now in operation there. This arrangement is due to Mr. J. Wigham, of Dublin, and is said to work very efficiently.

Messrs. Stevenson, of Edinburgh, have proposed that the Perkins engine should be employed as the motor for siren signals, but I am not aware that this suggestion has yet been carried out.

The adoption of the Siren as the most efficient sound signal for use in foggy weather, may be regarded as an important epoch in the history of the development of the use of such signals. Improvements have been made by Mr. James N. Douglass, engineer to the Trinity House; and Mr. Slight, Superintendent of the Trinity House work-shops, has invented an improved arrangement by which, instead of flat discs being used, the siren consists of two concentric cylinders, with slits in both, one inside the other, the outer one being fixed, and the inner one revolving, with the smallest possible clearance between them. The advantages of this arrangement are, that the suddenness of letting on or taking off the pressure is much increased, whereby the successive blows upon the air are rendered much sharper, and the sound intensity augmented. It is also

considered an improvement mechanically, by somewhat lessening the friction. Professor F. H. Holmes has succeeded in rendering the rotation of this siren cylinder automatic, with perfect control of the speed and consequent pitch, and an apparatus of this kind has not long since been fitted on board the light-ship at the Seven-stones.

It seems probable that before long the siren will be brought into more general use for maritime purposes. Already it has been introduced into the Royal Navy, for which service Professor Holmes has supplied three small-sized instruments. Messrs. Sautter, Lemonnier & Co., of Paris, have also produced a steam siren, which they claim can be used not only as a fog signal at lighthouse stations, but also for ships, and, in a smaller form, for locomotives, in the place of the whistle. Mr. Wigham, of Dublin, has also designed a form of siren for steamships, driven by a small turbine, actuated by the current of steam or air by which the instrument is sounded, the rate of rotation being controlled and rendered uniform by a simple governor.

Messrs. Sautter, Lemonnier & Co. have more recently introduced a double siren, in which two sirens, having different numbers of orifices in their respective cylinders, produce simultaneously two notes in the trumpet, and by this means the power of the instrument is more than doubled, and a characteristic feature is given to the sound.

It now remains to offer a few general remarks upon the subject.

It is obvious that, with the increasing use of sound signals, there is an increasing necessity for differentiating them. Something must be done to prevent one from being mistaken for the other: in fact, it is necessary that every signal should have its own characteristic. This essential element, as regards coast fog signals, has by no means been overlooked, and as each lighthouse is made to proclaim its own individuality, so every fog signal, established on our coast has been made to particularly indicate itself by some distinguishing feature. One great reason why explosive reports, whether from guns or rockets, are made use of, is because their sound is so entirely different from that of the blast of a siren, a reed horn, or a whistle. Indeed, the three latter strongly resemble each other, and can only be distinguished by trained ears. It has also been found useless to attempt to get differential signals by means of pitch of the note alone. To employ a high note at one station, and a low note at another, would, in the present condition of the musical cultivation of mariners, generally, be more likely to lead to confusion and disaster; although, as Sir Richard Collinson observed, in 1875, it might be possible to obtain an effective distinction by sounding a high and a low note in direct contrast. It has been frequently proposed to introduce long and short blasts; but here, again, experience has shown that many difficulties and risks would attend such an arrangement, and might result in conveying wrong information to the mariner, and lead him into danger. For real practical utility it has been found that, for the present, it is best to trust to the distinctions which may be obtained by varying the number of blasts, and the length of the silent interval. This is a system which is intelligible to the most ordinary understanding; and, accordingly, it is on this basis that the characteristics of sound signals are founded. By making the blasts to occur in groups, and varying the length of the intervals between the groups, on the same principle as that now applied to the new class of group-flashing lights, sixteen fundamental distinctions may readily be obtained, thus—commencing with an interval of half a minute:

1 blast	every	½	min.	3 blasts	every	½	min
"	"	1	"	"	"	1	"
"	"	2	"	"	"	2	"
"	"	3	"	"	"	3	"
2 blasts	"	½	"	4 blasts	"	½	"
"	"	1	"	"	"	1	"
"	"	2	"	"	"	2	"
"	"	3	"	"	"	3	"

The introduction of compulsory and optional sound signals in the new regulations for preventing collisions at sea, has naturally much extended the use of sound signals on board ship, and there can be no doubt that such signals should be entirely different from those made at fixed fog signal stations. It is said that already some difficulty has arisen in reference to the clause in the regulations, which enacts that in foggy weather a steamer shall sound a prolonged blast at intervals of not less than two minutes,

the fact being that several coast fog sirens sound the blast every two minutes. Unless checked, this, perhaps, is a danger likely to go on increasing as ships' sound signals become more powerful and more generally used.

One point occurs to me, in connection with those gentlemen who give much time, and trouble, and, probably, spend much money, in developing sound signals. I observe that they all take up some special code of signals, and then show how well their instrument is adapted for it. Now, if I might give a piece of advice to those gentlemen it would be, first look at the law, and see what signals are provided, then adapt your apparatus, whatever it may be, to making those signals. Don't require the law to be altered to suit your instrument—that is putting a real difficulty in the way; but make your instrument suit the law as it now exists.

I may remark it is not easy to see how the system of long and short sounds can at present be brought into satisfactory operation. Such distinctions are extremely pretty and simple upon paper, but they assume a vastly different aspect in the mind of an anxious and, perhaps, not over intelligent master mariner, on board his vessel, say in the Downs, in a thick fog. All around he hears horns and whistles blowing, and all he attempts to do is to keep clear of those vessels which, by the sounds, appear to be nearest. Of what use, then, would be the combinations of long and short sounds? Would he, in his bewildered state, care to try to distinguish between them? I venture to say he would have neither the time nor the inclination to do so; and it must not be forgotten that, in making provisions of this kind, it is not the skilled, clear-headed, highly-educated, Royal Naval or merchant captain you have to consider, so much as the thousands of experienced, weather-beaten master mariners, who know well how to navigate their vessels under trying circumstances, but whose minds are not adapted for comprehending any system requiring accurate and attentive observation, to which is tacked on the necessity of finding out the meaning after the observation is made.

As regards the present development of our coast fog signals, there is every reason for congratulation. This new branch of coast marking has been brought up to a very effective condition; no efforts have been spared to cope with the seaman's greatest enemy, fog, and the remarks which I have had the honor to address to you indicate with what success these efforts have been attended. By the aid of sound signals, the mariner is now enabled to continue his voyage with comparative safety, even when his vessel is enshrouded with a thick pall impenetrable by the keenest vision; and there is little doubt that those who have their business in the great waters are ready gratefully to acknowledge the humane spirit which has prompted the development of these signals, as well as the practical benefit which they derive from them.

ON THE ALTERATION IN THE DENSITY OF STEEL THROUGH HARDENING AND TEMPERING.

By C. FROMME.

From "Abstracts" of the Institution of Civil Engineers.

THE experiments were made first on four bars of the same dimensions, 100 millimeters (3.9 inches) long, and 7 milimeters (0.27 inch) on the side, and then on bars of the same length but of different sections. The results obtained are as follow :—

After hardening in cold water the density decreases, or in other words the volume increases ; the thicker the bar the less the increase.

After tempering the volume again diminishes, the increase being at "straw" reduced to one-half, and at "blue" to about one-fifth of the total increase gained after hardening, returning at "gray" to the original volume when soft. The molecular condition must, however, be

different, as the steel retains twice as much permanent magnetism in the "grey" temper as in the soft. If the bar is heated to a bright red and cooled slowly, the volume is larger than in the original state before hardening, the difference being about one-sixth the total increase gained after hardening. The question as to whether the density varies from the exterior to the interior of the bar, the Author proceeded to determine by eating off successive layers by acid, and determining the specific gravity of the remainder; but as a fissure was ultimately discovered inside the bar, the results must be considered untrustworthy. Further experiments in this direction are certainly desirable.—*Annalen der Physik und Chemie.*

A GRAPHIC METHOD FOR MEASURING CROSS-SECTIONS OF EARTHWORK.

Par M. H. WILLOTTE.

Translated from Annales des Ponts et Chaussées.

THE employment of graphical methods of solving problems tends to become more and more general. Every day methods are invented or improved, and the progress already made only calls more strongly for the attention of engineers to this subject.

We propose in this note to examine two problems, which are presented for solution whenever it is desired to estimate in an expeditious manner the area of a cross-section.

1st Problem. To construct the profile of a cross-section of earth work, and obtain its area, by a simple method.

Provide a series of sheets or cards representing the outline of the usual cut or embankment of a road or canal. These cards will bear certain lines and scales which result from what is to follow. Figure 1 shows, on a reduced scale, one of these sheets for the half profile of an embankment of a single track railroad.

What is required to complete the profile thus far exhibited? It is clear that nothing more is necessary than to draw the profile of the original surface. This may be done in a ready manner by the aid of a prepared scale, graduated to the scale of trigonometrical tangents, as shown in Table, Fig. 2.

This little instrument is then applied to the axis of the cross-section diagram at the cut or fill height, and inclined at the angle of the natural surface.

It only remains to follow with a pencil the edge of the protractor, in order to complete the half profile TNMP.

The length of the slope and the breadth of base are read at once from the inclined scale drawn on the prepared card.

It is required finally to determine the area TNMP. This is done in the following manner, which is only an application of a more general method for the measurement of areas.

If we consider some point A arbitrarily chosen on the movable scale, but having a position mathematically defined, it follows that for each position of A, a corresponding point on the engraved sheet may be determined.

We can, therefore, trace beforehand upon the prepared sheet a series of curves, giving the area of the half cross-sections for each position of the point A, and the problem is then solved by a simple reading.

For reasons, which will be immediately apparent, the point A is taken at A, the point of tangency of TN (original surface line), and the curve to which all the lines are tangent, which cut off areas equal to the area TNMP.

To determine the nature of this curve we seek for the position of the point of tangency A, under the above conditions. This point will be at the intersection of TN and another line T′N′, drawn infinitely near it in such way that the areas PMNT and PMN′T′ are equivalent.

Fig. 2.
y
D
N'
N'
Y
M
A
O
P
T
X

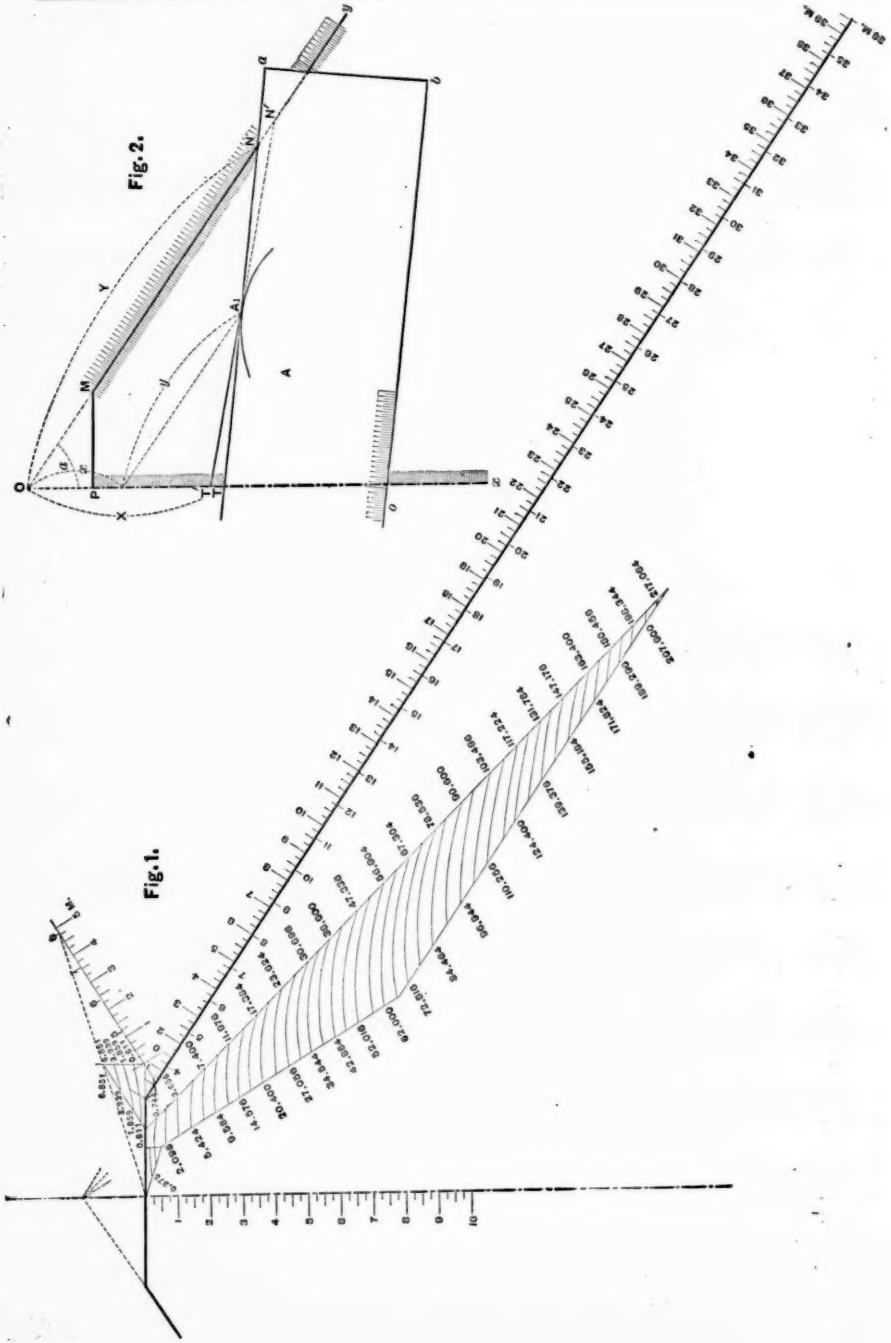


Fig. 1.

The two infinitely small triangles TA_1T and NA_1N are equivalent. Hence the point A_1 is at the center of the line TN.

To determine the equation of the curve of the locus of A_1 under the prescribed conditions. Let Ox and Oy be co-ordinate axes, and let $OT=X$ and $ON=Y$. The area PMNT being constant, the area ONT is also constant (so long as the line NT does not intersect the line PM within the angle xoy, a condition which is taken into account further on).

Then we have

$$\text{area} \quad OTN=\frac{ON\,.\,OT\,.\,\sin\alpha}{2}=\frac{XY\sin\alpha}{2}$$

or $$XY=4K^2 \text{ a constant.}$$

As x and y are the co-ordinates of A_1 we have

$$x=\frac{X}{2} \text{ and } y=\frac{Y}{2}$$

and $$xy=\frac{XY}{4}=K^2.$$

The locus of A_1 is, therefore, a hyperbola having for asymptotes the axes Ox and Oy.

For different values of K^2 we may obtain a series of hyperbolas corresponding to different values of the half section PMNT. These curves may be termed *curves of equal areas.*

The advantages arising from the selection of the point A_1 under the assigned conditions, are obvious.

1st. The curves of equal surfaces being hyperbolas drawn relative to the same point O, and to the same asymptotes, are easily traced. Any one is easily constructed by means of some one of its tangents, and others of the series are readily derived from this.

The preparation of the table of areas is not all complicated. An area is calculated corresponding to one of the curves. Other areas are determined by the law of the dimensions of similar surfaces, and the numbers may be written upon the curves.

If the curves are traced in such a manner that they cut equal segments on one of the radii vectores from the point O, the *second differences* of these numbers are equal.

2nd. For each of the different methods of choosing the point, there is a graphic table of determinate form; and for each table there exists a system of equal surface curves generated by the different positions of A corresponding to equal areas. The curves are generally of a degree above the second, but as we have already seen they become hyperbolas of easy construction when we take for auxiliaries points analogous to A_1.

But the simplicity of construction is not the only advantage arising from this selection; for it is clear that it is an advantage to diminish as much as possible the length of the curves of equal surface; in taking A_1 the minimum of length is secured.

Fig. 1 represents cross sections, comprised between the following limits:

1st. Inclinations of surface varying from -0.33 to $+0.33$.

2d. Depths or *fillings* at the center, of 10 meters.

The prepared sheet would not be inconveniently large if both these limits were extended. A single sheet might serve for cross sections of different slopes.

The mode of proceeding to employ the system is as follows:

1st. Make a book of the cross sections, also a sufficient number of the proposed sheets to serve the purposes of the work in hand.

2d. Write within the profile of each cross section, the center cut or fill and the slope of the original surface (expressed as a ratio or tangent of the angle made with the horizon).

3d. Proceed to trace the lines TN by aid of the movable scale (the inclination being measured by aid of graduations on the lower edge as at O in fig. 2).

4th. Read the numbers upon the curves to which in each case the line falls tangent, and write these areas within the respective cross sections.

It may be remarked here that the tangency of the line TN is easy to determine, and moreover that an error of the first order, in determining the point of tangency, results in an error of the second order only in getting the areas.

5th. Complete the calculations indicated for estimating the volumes.

As the accuracy of the work depends so largely upon the accuracy of the prepared sheets, it will suggest itself that a shrinkage of the sheet would result in

errors in the work. This does not necessarily follow except in cases obviously rare of unequal shrinkage in different directions.

In place of the movable scale for the measurement of inclinations, a common straight-edge ruler may be employed and the inclinations be obtained, by using the method of drawing parallels from a set of prepared lines like fig. 3, drawn to the different inclinations on each of the working sheets.

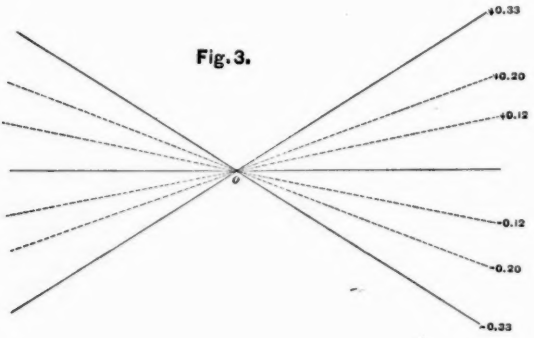


Fig. 3.

2d Problem. To determine with rapidity a large number of cross-section areas, by aid of graphic processes only.

This problem may be solved by aid of a diagram like fig. 4.

Draw the cross section P M N and construct very carefully the curve Su, the hyperbola whose tangents are TN and T′ N′ and also determine the area. (The position of the lines TN and T′N′ is determined without trouble, since OT $\times$ ON = OT′ $\times$ ON′ = a constant, and the curve Su can be traced accurately in a few minutes. The extreme points S and u are determined by the limits of the inclination of TN.) Draw also one of the radius vectors from O as OS and divide it into equal parts. Against each of the divisions write the area belonging to the curve passing through that point, if such curve were drawn according to the rule. The drawing is then complete.

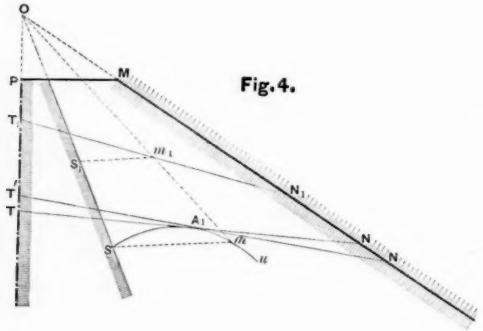


Fig. 4.

Its use is explained as follows:

Let T_1N_1 be a line of original surface. It is required to determine the area of PMN_1T_1.

Through the middle point m_1 of this line draw Om_1 meeting the arc Su in m

Join *ms* and then $m_1 s_1$ parallel to it. The number on the scale at S_1 is the area sought. This results from the property of the curves of equal surfaces described as above.

This process fails whenever the line T_1N_1 intersects the line PM within the angle TON. If many such cases occurred in any work a special construction easily devised might be prepared for them.

SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE.

By E. C. ROBINS, F.S.A.

A Paper read before the Royal Institute of British Architects.

E. C. ROBINS, F. S. A., said he thought those architects who, for the last thirty years, had practically proved their interest in sanitary science in so far as it related to architecture could not be otherwise than be pleased with the obvious improvement in recent public opinion, and the quickening of the professional conscience thereon. Having referred to the works of pioneers in sanitary science, to the disgraceful condition of London before the Great Fire, to the suggestions of Patte for improving the state of Paris in 1797, and to the great impetus given to the consideration of sanitary questions in England by the visitations of cholera in 1842, 1847 and 1852, in which latter year his own attention was directed to the matter, he said he proposed that evening to consider: (1). What had been defects in sanitary construction. (2). What were the remedies now generally available. (3). What further improvements were required. In London a system prevailed which compelled the professional architect to provide against the insanitary condition of the main sewers; he had to fortify the modern dwelling-house against sewer gas, which contaminated not only the air breathed by the inmates, but also the water they drank. It was not necessary to enter into much detail respecting sanitary defects. A summary was provided in a pamphlet entitled "Dangers to Health," written in a grimly-humorous way by Mr. Teale, surgeon to the Leeds Infirmary, and dedicated to his medical brethren. Such defects consisted not only in those things for which an architect might be blamed, but also in the faulty workmanship of artisans; in the jointing of bad iron and stoneware piping, in false levels and bad laying of drains, in perverse connections on the wrong side of traps, in ill-supported vertical soil-pipes, in the thousand evils emanating from the want of trained foremen and workmen. At the Conference on Public Health held in June last by the Society of Arts, Mr. Rawlinson had stated that house drainage was at the root of all sanitary reform, and that Earl Spencer's town house in St. James's place was the most perfectly drained house in London or elsewhere. The evidence given by Messrs. Eassie, Rogers, Field and Griffith, and other specialists before the Society of Arts, was referred to. The principles summarised by Mr. Griffith were quoted—principles which the author said were quite in harmony with many architects' previous practice. They were: (1). Communication between main sewer in street and house-drain should be disconnected or severed by an open-air space being left between house-drain and sewer. (2). The house-drain, air and water-tight, should be laid to such a fall as to be self-cleansing, free from deposit, and ventilated. (3). The soil pipe should be fixed inside the house and taken up full size above the roof. (4). The waste pipe should discharge into the open air instead of into soil pipes or a D trap. (5). There should be no means of drawing water from a cistern supplying a w. c., other than through the closet. (6). The waste pipes from sinks, baths, lavatories, &c., should be S trapped underneath, and made to discharge immediately into the open air, over trapped gullies. (7). There should be no connection with the main house drain, when laid underneath the house, except outside the main walls

of the building. (8). "Pan closets" with D traps should never be used, nor should D traps be fixed under sinks, &c. The evidence of Messrs. Eassie and Rogers Field coincided in all material points with that of Mr. Griffith. The author prefaced the subject of warming and ventilation, the second division of his paper, by quoting a remark made to him by Professor Jenkin, to the effect that the study and control of the pressure of the atmosphere, and not the temperature, is the key to all sound ventilation. As that pressure was increased or diminished in its utilization, so ventilation was promoted or retarded. Following the suggestion of Dr. Parkes, it was desirable to restrict the thing known as ventilation "to the removal by a stream of pure air of the pulmonary and cutaneous exhalations of men, and of the products of the combustion of lights in ordinary dwellings, to which must be added in hospitals the additional effluvia which proceed from the persons and discharges of the sick." It was not only important that the air should be changed, but also that it should be drawn from a pure source and carried through clean channels. By the term "ventilation" the author meant a passage for the wind, change of air or atmospheric recuperation. A way in was wanted for the air and a way out for it in every building or portion of a building. Natural ventilation was the simple process of allowing the external atmosphere to mingle with the internal atmosphere of a building. Scientific ventilation was the same thing, but with this difference: in the former case the air was free to mingle or not as it pleased, and in doing so it created many inconveniences; in the latter, direction was given to currents of air produced by interchange, and a healthy commingling of the oxygen with the carbonic acid gases was secured without the dangerous and disagreeable accompaniment of draught. The business of ventilation was to direct the pressure of the currents of air admitted and required to overcome stagnation under conditions where no draught was admissible. The natural process by which the temperature of the air was raised was two-fold: by radiation and by conduction. Radiated heat he defined as possessing the peculiarity of passing directly through any intervening space, without parting sensibly with its heat, and warming the first obstacle to its passage, such as a wall or window, with which it came in contact; conducted heat was the warmth given off from any surface by direct contact with any substance whether air or otherwise. The conducted heat of an open fire passed into the air, escaping by the chimney flue, and was lost for heating purposes; the radiated heat of the open fire was alone available for raising the temperature of a room. Draught, however, was almost inseparable from the use of open fires, especially when they were placed directly opposite doors, whereby large quantities of air were drawn across the floor and passed up the chimney. With reference to the size and position of "inlets" in rooms, it was desirable to make the area of each opening not larger than from 50 to 60 square inches, and they should be placed on the same side of the room as the fireplace. The introduction of air by vertical shafts, suggested by a Mr. Whitehurst years before Mr. Tobin was heard or even thought of, was a sound principle, suited to the requirements of ordinary rooms which were heated by the open fireplace only. Mr. Robins then drew attention to several varieties of stove and grate, including those invented by Mr. Phipson, by Messrs. Verity, and other architects, and, amongst others, described the heating and ventilating processes adopted by the late Mr. T. H. Wyatt, in the new Hospital for Consumption at Brompton, and also in the Norfolk Hospital at Norwich, built by the same architect in conjunction with Mr. E. Boardman, of that city. Dr. R. E. Thompson had, in a letter to Mr. Robins, thus summarised his views: "I think that air should be admitted at the level of the various floors, and not from an underground chamber; also that the air so admitted should come from the east and west sides if practicable, and in any case should be passed over tubes of hot water. Air of uniform temperature is disagreeable and oppressive; it is better that the upper air should be colder than that of the floor, and that the warm air as it rises from the floor-level should be cooled and agitated as it mixes with the upper air by the incoming cool-

er air. The foul air should be extracted by the open fire, and by the extracting flues at the top of the room, which should be heated by gas jets below, or made to communicate with a hot-air chamber above and in connection with turrets forming ventilating towers." With regard to w. c.'s, Dr. Thompson considered that the space they occupied should be heated to a higher temperature than the passages leading to them, and that a separate means of extraction should be adopted. In reference to systems of underground reservoirs or chambers for the accumulation of heated air to be transmitted through shafts to the different rooms of a building, everything depended on the cleanliness of those heated air-chambers. They were very difficult to keep clean, because they were out of sight, and were usually dirty and dusty; indeed, he had heard of some air-chambers in which decayed organic and vegetable matter had been allowed to accumulate; and of an instance in which a defective soil pipe had discharged into it part of its contents. Alluding to the various systems of heating, the author said that he had no great faith in any one of these, but that where he had to go beyond an open fire, in apartments too large for warming in that manner, he preferred hot water. Twice in his practice he had been obliged to substitute hot water for hot air, both instances being in churches. Two leading principles governed the supply of hot water for heating purposes, termed high pressure and low pressure. The latter provided for the supply of water at a low temperature, which cannot reach boiling point, in more or less large pipes; the former circulated water at a high temperature in strong wrought-iron pipes of very small bore, rarely exceeding an inch in diameter. The high pressure system, as now carried out, was as innocuous and quite as effective and manageable as the low pressure. After referring to various examples in his own practice, of which numerous illustrations in sections and working drawings were exhibited, Mr. Robins concluded with the assurance that the practice of Civil Architecture could not be divorced from the experiences of Sanitary Science. There was plenty of room for specialists and *dilettante* exponents—indeed, co-operation in overcoming the results of past carelessness was most needful; but the fact remained that dwelling houses, to be made healthy in the future, were and would still be the special province of professionel architects.

Dr. W. H. Corfield, at the invitation of the President, opened the discussion. A great deal had been said of late, he remarked, about the failure of architects to avail themselves of the advances of sanitary science; it was declared that they did not know their business; and all the failures in drainage and defects in ventilation of houses were laid to their door. For his own part, he had not found this to be the case. He had often met architects in consultation, and had always found them gentlemen who were able to understand all points that were raised, and he was glad to be able thus to acknowledge the courtesy with which he had always been met by members of the profession. Mr. Robins had told them that architectural practice could not be divorced from the experiences of sanitary science. He would go rather further, and say, if it had not been for the experiments that had been made by scientific men, no alteration in sanitary principles would have been carried out. For many years people had dealt with house drainage on a wrong system—that of bottling up foul air—and the erroneous method would probably have continued till now if it had not been for certain remarkable experiments, by which the real danger of sewer air—"gas" it was even now improperly called—was made apparent. It had been shown that enteric fever, and more recently that other diseases, were produced by a specific poison existing in sewer air, and communicable by contagion. Next it was ascertained that the poison was not the sewer air itself, but particles in that air, and it was now almost demonstrable that these particles were living germs, and the result was that people could now understand how they might prevent these particles from obtaining an entrance into their houses. But the practice of sanitary science had not been carried out, as the author said, "for a considerable number of years"—certainly not more than ten years—he might almost say six or seven. Disconnection of sewer and house drains had been shown to be essen-

tial by two sets of experiments; one proving that the dangerous particles could pass by absorption through water, so that a trap was no bar to the movement of foul air through a drain; the other, that when foul air was disturbed, as Dr. Franklyn had shown, it would pass through a water trap, and would be dispersed in the air above, contaminating it. Thus, while a water trap would partially prevent the passage of particles, it could not prevent the passage of foul gas. But it was now possible to make a house perfectly secure against the entrance of typhoid fever, and should the fever be imported by any person, it need not spread. Acting upon this knowledge, he had been able to state that a well-drained school in which typhoid occurred need not be closed, as if precautions were taken, the contagion could not spread. Although the principles of sanitary science were now perfectly clear and simple, yet to put them into practice was most difficult, especially in the case of an old London house, where it sometimes seemed impossible to put it into an efficient and healthy condition without pulling down the entire structure. To tell people to get a book on the subject and read it and put their dwellings in order, was as absurd as to tell a man to read a book on amputation, and then experiment by cutting off a friend's leg. One of the most amusing things was to go into a house where a man had tried to cure its defects himself. Often in houses which had been put in order by professional men, sore throat, sewer diarrhoea, and similar diseases were noticed. These showed that it was insufficient to disconnect the sewer and house drain, but that the waste pipes of sinks, discharged even into an open chamber, needed trapping. Air passed, during the night, through the air chamber into the house, and gave rise to the sewer diseases in question, so that a water trap was necessary here. The waste pipes of sinks were not proper ways for air to come into a house.

EXPLOSIVE GELATINE.

From Papers of the Royal Engineer Institute.

Explosive gelatine is a peculiar description of gun cotton, entirely soluble in nitro-glycerine, and forming with it a gelatinous or gummy substance, more powerful than nitro-glycerine, scarcely affected by water and giving out no trace of nitro-glycerine under the strongest pressure.

It can be rendered insensible to mechanical action, while retaining its power, by mixing it with certain substances soluble in nitro-glycerine, such as benzine, &c.

It is composed of 93 parts of nitro-glycerine, and seven of soluble gun-cotton.

The experiments demonstrated its insensibility to shock, to friction, and to the pressure or action of water; and further, that to produce complete explosion in a free state, and to develop the great force corresponding to its chemical composition, it would be necessary to use, even in its soft state, a peculiarly powerful detonator.

One gramme of fulminate of mercury was insufficient to detonate a charge in a a soft state, contained loosely in a tin case. Fragments of gelatine as large as a pin's head, or even of a small pea, were found scattered about after the explosion.

Under the blow of a pile engine, the gelatine was insensible to a blow of 3·5 kilogrammeters, while dynamite instantly explodes under one kilogrammeter.

The gelatine is unaffected by submersion in water, even at a temperature of 158° F., and showed no trace of exudation after eight days, at a temperature of 113° F.

From these properties it would appear very superior to dynamite for military purposes, provided a sufficiently powerful primer can be made to ensure complete detonation.

A new explosive suitable to all requirements has been prepared from this substance, and may be termed *gelatine explosive de guerre*. It is produced by add-

ing to the gelatine a small proportion of camphor, a substance highly soluble in nitro-glycerine.

A very small proportion of camphor renders the explosive insensible to blows, even of projectiles at short range, it also enables it to resist the action of water, and imports to it an explosive force far superior to dynamite or compressed gun cotton.

For complete detonation a special primer is needed of extra power, composed of a mixture of nitro-glycerine with a description of nitro-cellulose, prepared in a particular manner.

The composition of *gelatine explosive de guerre* is—

Camphor	4
Explosive gelatine	96
	100

Explosive gelatine consisting of—

Nitro-glycerine	90
Soluble gun cotton	10
	100

In appearance it is gelatinous, elastic, transparent, and pale yellow in color.

Its density is 1-6, it can be cut with a knife, and under the severest pressure it shows no trace of nitro-glycerine. At temperature of 122° Fahr. to 140° Fahr. it softens a little, but seldom becomes greasy.

When inflamed in the open air it burns like dynamite or dry compressed gun cotton.

200 grammes were placed in a tin cylinder six inches long. When ignited with a slow match penetrating the middle of the charge, it burnt quietly with a long yellow flame, though the case was closed with a metal cover. When half the charge was burnt the cover was simply raised by the pressure, without any explosion taking place.

A composition of 10 parts of camphor and 90 of explosive gelatine may be exposed for a week to a temperature of 158° Fahr. without showing any signs of decomposition.

4-4708 grammes of the same composition in a watch glass were exposed for seven hours a day during two months to a temperature of from 104° to 122° Fahr.

No decomposition took place, merely a partial volatization of camphor and nitro-glycerine.

After the experiment the specimen still weighed 4-1239 grammes, so that the loss of weight amounted to only .3469 grammes, or 7-7 per cent. As nitro-glycerine becomes volatile at 104°, part of the loss is accounted for, so that half the camphor in the composition can scarcely have evaporated, though the circumstances were exceptionally favorable to evaporation.

Experiments are needed to determine the rapidity of evaporation of the camphor, and the effect of its volatilization on the properties of the composition.

The preservative action of camphor, especially at exploding temperatures, is extremely notable.

Thus pure explosive gelatine, slowly heated, detonates at 400° Fahr., or rapidly at 464°.

If 10 per cent. of camphor are added it will not detonate at all when slowly heated, but becomes diffused in sparks. When heated rapidly, it explodes at a temperature too high for measurement by ordinary apparatus.

Mixed with 10 per cent., or even 4 per cent. of camphor, this substance will not explode at the same temperature as gunpowder, viz., 570° to 600°, but simply burns, producing sparks.

It may be inferred from the above that its liability to explosion from a blow would be equally slight, especially having regard to the elastic, gelatinous consistency of the material.

It requires a peculiarly powerful fuse to ensure the certainty of detonation. The inertness of the composition increases rapidly with the proportion of camphor. With the addition of only four per cent. detonation cannot be ensured with two grammes of fulminate of mercury, a primer of compressed gun cotton, or a mixture of 75 parts of nitro-glycerine with 25 of gun cotton, as used in the Austrian service.

A special primer is therefore required. It is composed of 60 per cent. of nitro-glycerine, and 40 per cent, of a nitrous substance, obtained from cellulose by a peculiar process.

Owing to the composition of cotton, it is impossible to obtain from it tri-nitro-cellulose. In Abel's process much of the cotton is only partially nitrogenized, and

some not at all, while Lenk's method is still less efficient.

If sulphuric acid be made to act upon cotton a white powder is obtained, named hydro-cellulose. This substance is extremely susceptible to the action of nitric acid. The result is, as regards explosive force, a highly nitrogenized description of cellulose.

This new gun cotton appears in the form of a fine powder resembling flour, but exhibits under the microscope the specific structure of cotton. It is not a great absorbent of nitro-glycerine like Abel's or Lenk's cotton, which are divided by mechanical means, neither does it share their property of becoming gelatinous with this liquid.

The mixture of 60 per cent. of nitro-glycerine with 40 per cent. of nitro-hydro-cellulose yields a soft, white, soapy, and entirely homogeneous substance. 20 grammes can be placed in an Austrian cartridge, which will hold but 15 to 17 of the regulation composition, and thus furnishes a primer capable of exploding *gelatine explosive de guerre*, and surpassing in detonating power all known exploding agents.

THE JORDAN BAROMETER.

From "The Builder."

It is impossible to foresee the result of the perfecting of any scientific instrument. It is rarely the case that such an instrument is—like the spiders among *insecta* and their allies—born in the form which it will maintain through life. Such, however, was the case with the weather-glass of Pascal. The best mercurial barometers of the present day are in principle, and almost in detail, identical with the tube, which that great genius carried up the Puy de Dome for his memorable experiment. The great defect of the mercurial barometer is the narrow limit of its movement. A difference of ten per cent. in the atmospheric pressure, which is about the maximum to be obtained at any fixed point on the surface of the earth, only causes a difference of 3 in. in the height of the column of mercury, and it is difficult to read the barometer more closely than to the tenth of an inch. The ball-like, or cup-like, form of the top of the mercury gives some indication as to the actually upward or downward tendency of the barometric movement; but the desirability of a more visible display of the force of atmospheric pressure is undeniable.

Extreme delicacy, no doubt, is obtained by the use of an aneroid, furnished with vernier and magnifying glass. But the aneroid is better suited for observations involving change of place than for those made successively on the same spot. Like the old-fashioned wheel barometer, the aneroid usually requires a tap, to see that the needle is freely moving; and this is but a clumsy means of making a delicate observation. Years ago we remember, in the window of an optician in Liverpool, an inclined barometer. The upper 3 in. or 4 in. of vertical tube were replaced by 5 ft. or 6 ft. of inclined tube, so that by placing the graduation at right angles to the latter, the intervals of change were magnified from twelve to fifteen times. We are not aware how the ingenious modification acted. Those of our readers who were at the meeting of the British Association in Birmingham, some fourteen years ago, may remember that one of the lions of the place was a water barometer, erected in the house of an amateur, which seemed almost to breathe like a living being. A water barometer was made by Professor Daniell for the Royal Society in 1830. The indications given by this instrument (the movement being about twelve times as great as that of the mercurial column) are very distinct. But the variation of temperature exerts such an influence on the vapor rising from the water within the tube as to interfere with the accuracy of the instrument. In fact, it is not a barometer, pure and simple, but a combination of barometer and thermometer.

Mr. Jordan, of the Museum of Practical Geology in Jermyn-street, has met, and it seems safe to say, has overcome this defect in the water barometer. He has substituted for water, pure glycerine, the specific gravity of which is 1.26—or only one-fourth more than that of water, And glycerine possesses the unusual advantage of combining perfect fluidity with a boiling point of 440 Fahr., and a correspondingly low freezing point. Thus, it raises no vapor to be affected by heat in the top of the tube, nor will it be injuriously affected by frost. The only defect of the substance is the readiness with which it absorbs water from the atmosphere. This has been met by Mr. Jordan, by the ingenious device of giving the glycerine a waterproof coat, or, in other words, floating a layer of petroleum on the surface of the glycerine in the cistern. Thus, a barometer of extreme delicacy, and as little liable to get out of order as the mercurial barometer itself, has been placed at the service of science.

One of these barometers has been constructed at Kew Observatory; a second at the Museum of Practical Geology in Jermyn-street; a third at the South Kensington Museum; and a fourth at the office of the *Times* newspaper. This journal has commenced the publication of two hours' reading of the instrument, plotted on the natural scale. The unusual weather, which has prevailed during the first week of these graphic indications, has been illustrated by the very visible movement of the surface of the glycerine. What is now most to be desired is the erection of an adequate number of these instruments at certain well-selected points in the island, and the publication of the contemporaneous movements of the column. The strong accentuation of the variations, already published, is such as to raise the hope that much valuable information may be secured by the proper multiplication of these delicate observations.

HISTORY OF ZERO.—"Zero" on the common thermometer, like the fanciful names of the constellations, is a curious instance of the way wise men's errors are made immortal by becoming popular. It may be worth while to say that the word itself (zero) comes to us through the Spanish from the Arabic, and means empty; hence, nothing. In expressions like "90° Fahr." the abbreviation, Fahr., stands for Fahrenheit, a Prussian merchant of Dantzic, on the Baltic Sea. His full name was Gabriel Daniel Fahrenheit.

From a boy he was a close observer of nature, and when only 19 years old, in the remarkably cold winter of 1709, he experimented by putting snow and salt together and noticed that it produced a degree of cold equal to the coldest day of the year, and that day was the coldest that the oldest inhabitant could remember. Gabriel was the more struck with the coincidence of his little scientific discovery, and hastily concluded that he had found the lowest degree of temperature known in the world, either natural or artificial. He called the degree zero, and constructed a thermometer, or rude weather glass, with a scale graduating up from zero to boiling point, which he numbered 212 and the freezing point 32, because, as he thought, mercury contracted the 32d of its volume on being cooled down from the temperature of freezing water to zero, and expanded 180th on being heated from the freezing to the boiling point.

Time showed that this arrangement, instead of being truly scientific, was as arbitrary as the division of the Bible into verses and chapters, and that these two points no more represented the real extremes of temperature than "from Dan to Beersheba" expressed the exact extremes of Palestine.

But Fahrenheit's thermometer had been widely adopted with its inconvenient scale, and none thought of any better until his name became an authority, for Fahrenheit finally abandoned trade and gave himself up to science.

The three countries which use Fahrenheit are England, Holland and America. Russia and Germany use Réaumur's thermometer, in which the boiling point is counted 80 degrees above the freezing point. France uses the centigrade thermometer, so called because it marks the boiling point 100 degrees from freezing point. On many accounts the centigrade system is the best, and the triumph of convenience will be attained when zero is

made the freezing point, and when the boiling point is put 100 or 1,000 degrees from it, and all the subdivisions are fixed decimally.

If Fahrenheit had done this at first, or even if he had made it one of his improvements after the public had adopted his error, the lack of opportunity which was really his, would have secured to his invention the patronage of the world.

LABOR OMNIA VINCIT.—We have recently had brought to our notice a remarkable example of the truth of the adage that labor conquer all things.

In 1866 a young man who had been blind from his birth applied for admission to Columbia College. After passing an excellent examination, he was admitted. He took at once a good rank in scholarship, which constantly improved, till at the close of his four years' course he was adjudged worthy of delivering the Latin salutatory at Commencement, the second honor in his class. He conquered his position by the most assiduous labor, under circumstances that might have appalled even a courageous man in the possession of all his faculties. He had prepared under his direction, or prepared himself upon card-board, in raised letters and diagrams, the text of the every-day lessons in classics and the necessary mathematical figures, such preparation often costing him three hours' labor for one lesson. With his raised letters and diagrams he could, by his delicate touch, read and demonstrate with great facility. His mind was eager and incisive, and his recitations became models of clearness and accuracy. He took high rank in every study, but ex celled in mathematics. Difficulties in this seemed to delight him. His fine mind and unflagging spirit never rested till all difficulties had been overcome, and he was master of the subject. After graduation, he taught private pupils, and in such intervals of leisure as he had he continued and extended the study of mathematics. Some two or three years ago, he found that the satisfactory solution of a problem upon which he was engaged required a knowledge of the calculus of variations—an abstruse branch, to which he had paid little or no attention. He immediately, *suo more*, began a thorough investigation. He gathered, by purchase and from private and college libraries, all that was to be had upon the subject. He found that nothing of importance concerning it had ever been published by an American author; that the only systematic work upon it that ever appeared in English, published in England thirty years ago, was out of print, very difficult to obtain, and that since its publication the subject had been greatly extended and improved by the labors of English, French, and German mathematicians; that the results of these labors were inaccessible to the general reader, being contained in communications to mathematical journals and learned societies, or in certain special works. He thereupon undertook the preparation of a treatise which should present in a simple manner everything at present known concerning this branch of mathematics. He knew nothing of the French and German languages; he had translated to him, often by people who could simply translate the words and not the sense to him, the French and German essays; and thus, in physical darkness, but in the clear light of his own mind, he wrought simplicity out of complexity. The only amanuensis accessible to him was a person ignorant of mathematics, which increased the embarrassment under which he labored. To this amanuensis he dictated his work, which is now completed, and is believed to be the only thorough, simple, and systematic treatise on the subject in the English or, perhaps, in any other language. The name of this work, which would be a credit to any man, and which under the circumstances, is simply marvelous, is *A Treatise on the Calculus of Variations*, by LEWIS B. CARLL, of Flushing, Queens County, New York.

He has one more difficulty to overcome in connection with it, and that is in its publication. His publisher* requires subscriptions for 300 copies before he will undertake it, and these Mr. CARLL, besides giving away his labor of years, has courageously undertaken to procure. There can be no doubt that he will succeed, for surely labor, properly directed, conquers all things.—*Harper's Weekly.*

* The work will be published by D. VAN NOSTRAND, 23 Murray Street, New York City, who will give any information with regard to it that may be desired.

REMOVAL OF SILT FROM THE BACK OF RESERVOIR DAMS IN ALGERIA.

By MARTIN CALMELS.

From "Abstracts" of the Institution of Civil Engineers.

Some experiments were made last October, at the Sig reservoir, on the Author's method for removing silt from reservoirs by means of jets of compressed air. Full details are given of the apparatus employed, which consists essentially of a compressor, an accumulator, and a pipe for directing the jet. The accumulator is made of three galvanized plate-iron cylinders, each 6½ feet long, 13 inches in diameter, and nearly ¼ inch thick, and calculated to resist a pressure of 85 lbs. on the square inch. A pipe, 1 inch in diameter, conveyed the compressed air from the accumulator, over the reservoir dam and down the other side, on to a double pontoon floating on the reservoir lake, through the centre of which the tube of the air jet is directed as required. Two india-rubber tubes, each 50 feet long, serve to connect flexibly the iron pipe passing over the dam with a floating pipe, and the floating pipe with the jet. The nozzle at the end of the directing tube is conical, and has eight holes at the side $\frac{1}{10}$ inch in diameter. The rate of the current of air, under a pressure of 57 lbs. on the square inch, in a depth of water of 16 feet, would amount to 1,600 feet per second. With an 8 HP. engine, the jet can be worked continuously under a pressure of 5 or 6 atmospheres. Another jet with a single orifice, ½ inch in diameter, has been made for working at a lower pressure. The action of the jet proved very satisfactory in stirring up the silt; and by opening the sluice gates at intervals, after working the jet in the deposit near the dam, a considerable quantity of silt was discharged with the water. As the silt, though sometimes forming a hard crust at the surface in dry weather, remains fluid below, the jet would gradually lower the deposit all over the reservoir by merely working near the dam, as the silt higher up would by degrees slide in and fill up the void made at the dam. The process, morever, would serve not merely for keeping new reservoirs clear, but for removing accumulated masses of deposit from old reservoirs. By proper management, the Author considers that a large deposit might be gradually removed without interfering with the agricultural interests; and that by introducing the stirred-up silt, at suitable times, into the irrigation canals, it might be beneficial in fertilizing the land. Also by removing the silt close to the dam, which frequently prevents the lifting of the sluice gates, the Author thinks a better system of gates might be adopted, which, by being contrived to open rapidly, would increase the scouring action at the sluices.—*Annales Industrielles.*

Calculation of the Strength of Cylindrical Vessels. — The author draws attention to the inaccuracy of the formulæ given by Barlow, Brix & Lamé, for calculating the strength of cylindrical vessels, and states that they are all based on the tacit assumption that k, the admissable stress on the material of the cylinder, is identical with the greatest occurring tension; this, the author asserts, is not, as a rule, the case; in general it is not the greatest stress existing in any part of the body under consideration which is of importance, but the greatest elongation (or compression), the latter being only in special cases—simple tension (or compression), bending or shearing, combinations of tensile (or compressive) and bending, or shearing and torsional strains—directly proportional to the maximum stress. Grashof, whose formulæ are also quoted, has

taken account of this, but neglected the influence of the pressure in the direction of the cylinder axis, as have also Barlow & Brix.

The author, in developing his formulæ, avoids the inaccuracies mentioned, and arrives at the following results:

for internal pressure p

$$r_2 = r_1 \sqrt{\frac{k+0.4p}{k-1.3p}};$$

for external pressure p_0, assuming that collapse is out of the question,

$$r_2 = r_1 \sqrt{\frac{k}{k-1.7p_0}};$$

where r_1 = inside radius of cylinder,
r_2 = outside " "
k = admissable tensile strain.

—(*C. Bach, in Zeitschrift des Vereines Deutscher Ingenieure*).

THE FAILURE OF A DOCK WALL IN THE EAST INDIA DOCKS.

By LIEUT. H. D. LAFFAN, R. E.

From the Papers of the Royal Engineer Institute.

About the beginning of July, 1879, a serious settlement took place in the south wall of the East India Import Dock. The wall in which the failure occurred was built of brick and stone lime mortar. The brickwork was apparently very good, the wall having in one place sheared straight through the bricks, leaving the joints undisturbed.

For a length of about 700 feet the wall had sunk down to a depth of several feet, and in its final position had assumed an irregular wavy outline, the greatest bulge (at the footings) being 7 feet 3 inches, and the greatest subsidence 5 feet 3 inches. The forward movement, however, was almost entirely confined to one point, and was probably caused by a heavy crane fixed just behind the top of the wall on an iron framework. As the wall sank the crane fell backwards, acting with a leverage upon the wall and driving it forwards.

At the western end of the settlement the wall had sheared downwards, leaving a fissure 1 foot wide, with a step 2 feet high at the top; at the east end the shearing was distributed over a number of smaller fissures. No part of the stuff at the back of the wall had found its way into the dock, but had sunk down, forming a trench behind the wall, in which, in some places, there was a depth of as much as 15 feet of water.

A large warehouse, only 50 feet distant from the edge of the wall, had shown no sign of settlement; this may be accounted for by the fact that they were built on a solid layer of concrete, 13 feet thick. The dock wall in which the failure occurred was built without a foundation of piles, upon cross planking, laid on gravel and sand some 2 feet deep, overlying running sand, and the settlement appears to have resulted from the sand being drawn away from under the wall.

The immediate cause of the settlement appears to have been the tapping of the running sand in the course of excavating works in connection with the Midland Railway Docks, about a quarter of a mile distant, when a "blow" ensued which covered in the works with sand to a considerable depth. The sand was allowed to run for several days, and while it was running the settlement occurred in the wall of the East India Dock. At about 5 A. M. one morning the wall sank down suddenly without any previous warning, the greatest subsidence at first being 3 feet, but it afterwards continued to sink gradually as long as the flow of sand in the Midland Railway Works continued, and when this was stopped the settlement ceased.

At one time there was a channel from the bend of the River Lea, into the River Thames, about where the Midland Railway Docks now are, and although the channel has been stopped, there is probably still a creek of sand running in

this direction through the East India Import Dock, and under its south wall, which has been tapped by the Midland Railway Company. The sand had thus, in all probability, been drawn away from under the wall, which, after supporting itself across the gap for a time, after the manner of a beam, eventually gave way suddenly under its own weight.

This accident has occurred at a time when there is a pressing want of acommodation on the quays of the East India Docks; it has, therefore, been thought desirable to widen the wharf on this quay, as well as to restore it as rapidly as possible. For this purpose a wooden staging is to be erected about 30 feet to the front of the present wall; the wall itself will be left as it is, and a mass of concrete, resting against its base and sloping up to the top, will be laid between the wooden staging and the wall, in order to prevent any further forward movement.

STREET LIGHTING (ELECTRIC) IN LONDON.

THE meeting of the City Commission of Sewers was held recently to consider the tenders submitted for lighting during one year three districts of the City, in answer to the applications made some time since. The offers from the representatives of four different systems were considered. The first district comprises Blackfriars Bridge, New Bridge Street, Ludgate Circus, Ludgate Hill, the north side of St. Paul's Churchyard, and Cheapside as far as King Street. The particulars of the tenders for this district were as follows:

—	Cost of working for 12 months.	Cost of fixing and removing.	Total.	Number of lights.	Candle power per light.	Total candle power.	No. of gaslights replaced.
	£	£	£				
Brush.....	660	750	1410	32	2000	64,000	150
Crompton...	2007	500	2507	17	4000	68,000	152
Siemens....	2050	1650	3700	29	—	47,000	144
Jablochkoff.	1500	1550	3050	48	500	24 000	144

The 29 Siemens lamps comprised 23 smsll ones of 500 candle power each, and 6 large ones each of 6000 candle power. The Committee recommended that the tender of the Anglo-American Electric Light Company (the Brush system) should be accepted. The second district embraces Southwark Bridge, Queen Victoria Street, the lower part of Queen Street, and Queen Street Place. The tenders considered for this district were as follows:

—	Cost for 12 months.	Fixing and removing.	Total.	Number of lights.	Gas lights replaced.
	£	£	£		
Crompton.....	2167	560	2727	16	176
Jablochkoff.....	1580	1350	2930	12	161
Siemens..... ...	1850	980	2830	31	164

The 31 Siemens lights would consist of 26 small and 5 large lamps. It was recommended that the contract for this district should be given to the Electric and Magnetic Company (Jablochkoff system).

The third district refers to London Bridge, the upper part of Queen Street, Cheapside, King Street, Guildhall Yard, the Poultry, Mansion House Street, the Royal Exchange, King William Street, and Adelaide Place. The tenders considered for this section were :

—	Cost for 12 months.	Fixing and removing.	Total.	Number of Lights.	Gas lights replaced.
	£	£	£		
Crompton...	2475	650	3125	18	132
Seimens.....	2270	1455	2726	32	138

The Siemens' lights will consist of 26 small and 6 large ones. The lighting of this district was awarded to Messrs. Siemens Brothers. Some idea of the different modes of installation proposed

will be gathered from the following particulars: The Anglo-American Light Company will fix their lamps on separate posts, not less than 13 feet above the ground. Overhead wires will lead from the company's Victoria Works, Vine Street, Lambeth, where the power will be located, and then from post to post, overhead, except across the streets, when they will be carried underground. Messrs. Crompton & Co. suggested employing lamps capable of sliding up and down posts, or suspended across the streets, and to be lowered by cords and pulleys. Upon the bridges the lamps would have been carried on posts 35 feet high. The electric and Magnetic (Jablochkoff) Company will carry out the same system as on the Embankment, the wires being hung from lamp to lamp, and carried over the crossings, on high posts. Messrs. Siemens Brothers will employ large lamps in clear glass globes, with umbrella-shaped reflectors, placed on posts 70 feet or 80 feet high, and small lamps in partly or wholly frosted glass globes, on 20 feet standards. The wires will be laid underground, and the light-producing plant will consist of two 12 horse power semi-portable engines, seven medium-sized dynamo-electric machines, and the alternate current machines, with their excitors. In making their report and recommendations, the Street Committee stated that they had been guided not only by the prices given in the tenders, but by the effect produced with the different systems in actual operation, all of which they had seen.

REPORTS OF ENGINEERING SOCIETIES.

BOSTON SOCIETY OF CIVIL ENGINEERS.—At the December meeting a memoir of Ephraim N. Winslow, late Chief Engineer of the Old Colony Railroad, was read by Mr. Doane.

A description of the Old Mill Dam wall was presented by E. W. Howe.

A paper on "Additional Width of Gauge on Railroad Curves," was read by Thos. Doane.

ENGINEERS' CLUB OF PHILADELPHIA.—The annual election in January resulted in the choice of the following officers:

President—Strickland Kneass; *Vice-President*—Henry G. Morris; *Recording Secretary*—Wilfred Lewis; *Corresponding Secretary*—Howard Murphy; *Treasurer*—A. R. Roberts; *Board of Directors*—Frederic Graff, Rudolph Hering, J. J. De Kinder, T. M. Cleemann, Geo. Burnham, Jr.

The papers presented at the meeting of January 15th, were the following:

"Canal Routes Across the Isthmus of Panama," by Col. James Worrall.

"Progess and Methods of the Geological Survey of Pennsylvania," by Charles A. Ashburner, M. E.

"The Use of Dynamite for Blasts," by W. Rodman Wharton, C. E.

"Notes and Illustrations of Mine Topography," by Charles A. Ashburner, M. E.

"Estimates and Improvements in Diamond Drilling," by Chas. E. Billin, M. E.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—The growth of the Society leads to a demand for more ample space.

A circular has been issued to members, and is to be extended to others who are interested in the advancement of engineering, the purport of which is, that the Board of Direction solicits contributions to a building fund, the amount of which shall be $25,000 or $30,000. The names of contributors to the fund will be regularly enrolled and published in the proceedings. A subscription of $100 entitles the giver to a copy of the monthly publications for life.

THE POLYTECHNIC ASSOCIATION OF THE AMERICAN INSTIUTE held its regular weekly meeting on the evening of the 6th inst. Thomas D. Stetson, presiding.

A newspaper scrap was read announcing a newly-discovered process for the preservation of dead bodies, originated in Germany and patented here; but the patentee had been induced to abandon his patent and make it public property for the benefit of the world. A liquid was made by which the bodies were embalmed by being saturated and impregnated with it. Three thousand parts water, one hundred alum, sixty potash, twenty-five common salt, twelve saltpetre and ten arsenic acid was made the first composition. Then to ten parts of this, four parts of glycerine and one of methyl alcohol were added. Bodies preserved by this were alleged to fully retain their form, color and flexibility for years.

In the discussion it was doubted that the color would be preserved. There were compounds which would preserve human bodies very prefectly, if they could be thoroughly impregnated before decay had commenced. A company in this city, the New York Sanitary Company, furnish a fluid and instruments for applying it, by which the interiors are very thoroughly impregnated before decay commences. Then a moderate treatment on the surface with the same or other preserving fluid insures the preservation of the body in a high degree of perfection for a long period. The body of the well known actor, Mr. Porter, who was killed in Texas, was preserved by the aid of this process and brought to this city, and seen by his friends at the funeral fourteen days after death.

An account was read from *Iron* of a process of printing many colors at one operation, alleged to be in successful operation in France. A solid block was formed in Mosaic of diffe

ent colors, using blocks of pigments all capable of being acted on by a chemical or combination of chemicals. A thick mass of this is mounted in the press, planed off smooth, and then wetted rapidly on the surface with the proper fluid, and the paper or other material placed thereon and pressed. A clear impression is thus obtained in all the colors, and in the case of textile fabrics the color goes completely through their substance. After exposure for a brief period to heat, to drive off the fumes of the chemicals employed, the work is finished.

Mr. MacDonald said he had assisted in trying similar experiments in this country. In those experiments glycerine was used, and the printed impressions had the peculiarities due to the presence of glycerine, that they remained damp. The process, so far as he had known it, had been always a failure. The sharpness of the impressions would be satisfactory to some, but not to a good printer, and the character of the work generally was inferior.

Mr. Blanchard developed on the blackboard a mode—original with him, for computing the strains on the different parts of bridges. Eddy, Stoney, Dubois and others had analyzed with immense fineness, but their methods were too complicated. It could be done much more simply. The relative strains on every part were ascertained by geometrical figures. The operation was rapid and sure. It was an improvement on the ordinary diagram for the decomposition of forces. The vertical strains were represented by horizontal rather than vertical lines.

The discussion following developed singular anomalies in the failure of bridges. The Montmorenci bridge, near Quebec, after bearing immense loads for a long period, fell suddenly with nothing on it. It appeared that the fracture, of iron wrought under continued strain, was a gradual process, the catastrophe occurring as the result of a slow failure which had been initiated much earlier. Mr. Hudson referred to the failure of the chain bridge across the Merrimack River in 1826 after a heavy snow storm.

The President referred to the great perfection which theoretical and practical science has been brought in modern bridge building, as exemplified in the costly East River Bridge, which we hope will prove, as it promises, a master-piece of the art. He also mentioned the two famous bridges near each other at North Bangor, in Wales—one, a suspension bridge completed in 1825, before the superiority of small wire cables for such purposes had been established. Wires were immensely easier to stretch across one at a time and were found much superior in strength for a given weight when completed. That bridge was built with what are sometimes termed pitch-chains, bars of iron laid three or four abreast and knuckled together by transverse pins through their ends. It continues to be used for general carriage traffic. Near it is the famous tubular bridge engineered by Stevenson & Fairbairn, which carries the railway trains between Anglesea and the main island of Great Britain. Shipping moves under both bridges through the Menai Straits.

An extract read from the editorial correspondence of the *Philadelphia Press* of last summer, developed a long conversation with one of the leading silk manufacturers of Lyons, in which he sadly admitted the competition, dangerous to their industry, of Americans, in the silk manufacture. In the discussion which followed, it was stated that there are now about 200 separate manufactories in America for woven and sewing silks. American manufacturers load their silks with less foreign matter and make an article which is superior in wear but not as brilliant in gloss. Paterson, and other points, manufacture ribbons with eminent success. Hartford manufactures dress goods of sombre colors superior to any in the world. We import about 7,500 tons per annum of raw silk and manufacture it here. The raw silk made in this country is slight. Wages are too high. It requires cheap labor as in Italy, China, &c. Machinery has not yet succeeded in reeling cocoons.

But immense areas of our country have mild winters and are every way favorable for the silk worm. We can raise cocoons and ship them abroad to be reeled and returned. We are producing cocoons largely in North Carolina and California.

A paper read by Professor De Volsen Wood opened the main subject of the evening, the "Relations of Machinery and Labor." He held that the present era of machinery has induced great revolutions in labor and laborers, but the general effect is eminently beneficial.

The farmers of Ohio opposed railroads in the belief that they would diminish the demand for horses and oats, until it was shown that the introduction of railroads resulted in an increased price for both, in every instance. A machine which made one man do the work of ten, at first sight appeared to dispense with the labors of nine, but labor is more constantly in demand and better paid than before machinery was introduced. A farmer's wife in the West told him that their reaping machine, by reducing the number of men to feed during harvest, had lightened her work more than her sewing machine. The increased production of the earth must result in greater wealth to the world. Fifty thousand reaping machines involve in the first instance, a quickened demand for metal, wood, skilled labor and means of transportation. It calls for buildings, clerks, and agents. The wealth it produces calls for buildings, stock, carpets, music, books, and works of art. Thus, apparently unconnected branches of business are benefited by the reaping machine.

The discussion following questioned one proposition: It was doubted whether the reign of machinery tended to narrow the faculties by confining a man to one branch of labor. Formerly a long apprenticeship trained the faculties to the production of a wrought-nail or a pin-head and there stopped. The apprentice system is gone. There is danger from its absence, but so far, in America at least, the intelligence developed by the schools, gen-

eral and technical, have successsully taken its place, and all are mobile. Our great manufactories, with their hum of machinery are schools to every young man and warn him that he should be ready for emergencies. We have no indolent rich, no idle class except the tramps, and they are disappearing. All can, and do, work with head or hands, and nearly all can change successfully from one business to another with only three weeks of special training.

ENGINEERING NOTES.

SAFETY ARRANGEMENT FOR WATER PIPES. In order to obviate the very common evils connected with the bursting of water pipes in winter, Herr Weissbarth has contrived an arrangement (we learn from the *Deutsche Industrie Zeitung*) by which any water that may escape thus is carried off into the street drain or a cesspool, and, at the same time, a cheap mode of heating the whole pipe system with a single gas or petroleum flame is rendered possible. The entire system of water pipes, which, as in every right arrangement, must have, in all its branches, falls toward the ascending pipe, is inclusive of the ascending pipe) inclosed in sheet zinc pipes of 5 to 8ctm. internal diameter; so that water finding exit at any part of the system gets into the inclosing pipe, and is carried away. The inclosing zinc pipes, about 1 meter long, are not soldered at the joints; but stuck into each other like gutter or waste pipes, and the water pipes, of lead or iron, are fixed in the others by means of rings with small projecting pieces bent at a right angle, which catch in metallic tholes soldered on the interior of the zinc pipe. The lowest inclosing pipe has a bottom, through which the water pipe passes tightly, and close above this is the tube by which the escaping water is carried off to the drain. In order to get at the water pipe without having to take the zinc pipes out of each other, some of these are furnished with doors 70 to 75ctm. long and 5 to 6ctm. wide, which are easily slid within the tube, as they are led above through a soldered metal ring, and below through packing; the latter at the same time prevents the water flowing out between the doors and the pipe; moreover, the longitudinal borders of the doors are packed interiorly, so that the water follows the packing and does not issue by the door. The fixing of the zinc tubes to the walls is effected with rings on which they are supported with noses. Branch pipes are soldered into the main pipe. When, in a branch pipe, stopcocks occur, the inclosing pipe is there perforated for the spindle and stuffiing box. In the longer branch pipes, as in the vertical ascending pipes, doors must also of course, be introduced in the inclosing pipes, the openings being naturally on the upper side. At places where the ascending pipe is exposed to cold, as, *e. g.*, in water closets or entrance halls, the arrangement permits readily of a warm aircurrent being produced in the inclosing pipe, by means of a gas flame (which may also serve in illumination). To this end the pipe is furnished with an oblique branch directed upwards, and bent round to terminate in an iron or brass funnel, under which the gas or petroleum flame burns. The heat then passes into the inclosing tube. In the air box above holes are provided to let the air escape, and good ventilation may thus be secured.

In order to facilitate repairs, the water pipe, at the middle of the doors of the inclosing pipe, is formed with brass connecting screws. But the use of the ordinary soldered junction does not present any hindrance by reason of the zinc tube. Nor are any other serious difficulties, it is said, encountered in the working of the system.

UNITED STATES SUBMARINE SURVEYING.—The present year's submarine survey work of the United States Government was undertaken with the object of determining the exact relation of the fauna of the Atlantic Ocean with that of the Gulf of Mexico and the Carribean Sea. The deep sea soundings ranged chiefly between 450 and 800 fathoms, and the work begun in June last, was carried on about 120 miles from the coast, and, generally parallel to it, commencing south of Cape Hatteras. The sea bottom has been shown, by these explorations, not to be gently sloping, but there was found the continuation of the plateau of which the northern portion extends as far as Cape St. George, the southeasterly limit reaching to the Bahama Banks. The work of exploration was confined during the past season to the western slope of the plateau, the sides of which are so steep, that in the distance of a few hundred feet, the depth of soundings increased from 100 to 450 fathoms. This side of the plateau is covered with a rich deposit of mud and alluvium, gathered from the discharge of numerous rivers and washed off the top of the plateau by the action of the Gulf Stream. The result of this action has been, that while no animal life has been found to exist on the top of this submarine highland, except certain coral formations, the conditions of the slope are highly favorable, and the numerous specimens obtained showed that, generally, the animal life corresponds with that in the Gulf of Mexico and the Carribean Sea. During the course of the survey, work was continued day and night, and eight dredgings were generally made during the twenty-four hours.

THE NEW TAY BRIDGE.—The sketch plans prepared by Mr. W. H. Barlow, C. E., London, in connection with the Parliamentary notices already published for the erection of another Tay Bridge, have been issued. While these plans do not show the structural details, it is understood that the bridge is to be of sufficient width to admit of a double line of rails being laid, and that in the arrangement of the girders the rails will be laid partly along the lower and along the upper booms, the permanent way being enclosed on each side by a strong iron parapet. The new bridge is to be erected a little to the west of the present one, the intervening space between the centers of the bridges being about 50 feet in width, and

the course it takes is in a line with the old bridge. At the north shore it joins the existing viaduct at Magdalen Yard Point. In the bridge there will be 75 spans in all, the four highest being opposite the four broken piers at the south end of the gap in the present bridge. Their width will be 229 feet each, and height 77 feet above the high water level of ordinary spring tides, being 11 feet lower than the highest spans in the old bridge. The height of the first span on the Fife side is to be 65 feet, and the 22 succeeding spans gradually decline in height to 60 feet 6 inches. The four spans, 77 feet high, follow, and then the height of the remaining spans corresponds to the declinature of the bridge towards the north shore, where the spans are 23 feet high. The width and height of the different spans, beginning from the Fife shore, are as follows: One 100 feet span, 65 feet high; ten 106 feet spans, varying from 65 to 63 feet high; twelve 132 feet spans, varying from 63 to 60 feet 9 inches high; one 130 feet 6 inches span, 60 feet 6 inches high; four 229 feet spans, 77 feet high; one 229 feet span, 74 feet 9 inches high; one 211 feet span, 72 feet 9 inches high; two 229 feet spans, varying from 72 feet 9 inches to 68 feet 6 inches high; one 211 feet span, 66 feet 6 inches high; four 229 feet spans, varying from 66 feet 6 inches to 58 feet high; one 148 feet span, 40 feet high; eleven 117 feet spans, varying from 40 feet to 27 feet 6 inches high; twenty-four 63 feet spans, varying from 35 feet to 19 feet 5 inches high; two skew openings, 50 feet span each, and 23 feet high; six 27 feet spans, 23 feet high; three 27 feet spans, somewhat less in height, and last of all the present arch span 100 feet in width and 18 feet in height, which crosses the esplanade on the Dundee side of the river. The gradients are shown to be as follows: From the first span at the Fife side to the twenty-second the line has an inclination of 1 in 733, then it becomes level, and continues so for about 1000 feet, when it begins to fall towards the north shore at the rate of 1 in 114, until it reaches 1 in 76 at the viaduct, and at about that gradient the line is carried into the Tay Bridge Station, where it becomes level. The plans show the abandonment of the present objectionable junction of the Newport line at the south end of the bridge, and the substitution of another junction, which will likely be satisfactory.

IRON AND STEEL NOTES.

THE Customs' returns for the past month show that there has been an export of 83,905 tons of pig iron from English, Scottish, and Welsh ports, and that Middlesbrough exported more than half of this—44,848 tons. Barrow-in-Furness ranks second, having exported 8,230 tons; and then follow Glasgow, with 7,655 tons; Newcastle, 5,081 tons; Grangemouth, 3,650 tons; Liverpool, 3,454 tons; West Hartlepool, 3,360 tons; Whitehaven, 2,760 tons; Stockton, 1,878 tons; and Troon, 1,700 tons. None of the other ports enumerated have shipped more than 655 tons. Of bar and bundle iron, the largest shipment—10,904 tons—is from Liverpool, the amounts from all other ports being comparatively small. Of rails, Hull, Liverpool, Barrow, Middlesbrough, and Cardiff—in the order named—were the only ports exporting large quantities.

IN a paper "On the Determination of Phosphorus and Silicon in Iron and Steel," in Dingler's Polytechnisches "Journal," Mr. A. E. Haswell describes a new method of analysis, in which the whole of the electro-negative substances present in the metal are obtained in the insoluble residues, the iron being completely separated in solution as the first operation. The sample, in the form of filings or borings, is treated with a 7 per-cent. solution of double chloride of copper and ammonium, at the lowest possible temperature in a corked flask. About twelve hours are required to effect the solution, the flask being frequently shaken. If the proper equivalent quantities of the double copper salt are taken, the iron will be completely dissolved as ferrous chloride, free, or nearly so, from copper, while the carbon, silicon, sulphur, and phosphorus will remain in association with the reduced sponge of metallic copper. This, when carefully washed, is dissolved in nitric acid, the silicon determined by evaporation to dryness and calcination, and the phosphorus by precipitation, first with molybdic acid, and then with magnesia in the usual way. The author gives several examples showing that the molybdic acid precipitation is not affected by the presence of copper salts in the nitric acid solution.

STEEL MAKING IN CHINA.—In the manufacture and use of steel, the Chinese appear to have attained a very early and remarkable proficiency. Chinese records do not enlighten us as to the precise period at which the art of reducing metals from their ores became known in that country; but it is evident that it must have been some centuries before the Christian era. Mention is made of steel in the most ancient of the Chinese writings, and Leih-tze, an author who flourished about 400 B. C., described the process by which it was made. In the Yu Kung section of the Shoo King, Book I., it is stated that among the articles forming the tribute of Yu were nautical gem stones, iron, silver, steel, stones for arrow-heads, &c. Legge points out that, in the time of the Han dynasty, ironmasters were appointed in several districts of the old Lian-Choo to superintend the iron works. With the exception of this passage, however, it is considered probable that there is no distinct allusion to iron in Chinese writings older than 1000 B. C. Steel continues to be manufactured in China up to the present day. Mr. James Henderson, a commissioner of Li-hun chang, the governor-general of Chililli, a minister of the young King of China, states that the "steel which comes to Tein-tsin from the Upper Yang-tse is highly prized, and bears much higher prices than the Swedish steel imported into China."

SPANGENBERG'S EXPERIMENTS ON THE STRENGTH OF IRON AND STEEL.—A Werder testing machine, maximun pull 100,000 kilograms (100 tons) was erected, and a Klebe

measuring apparatus was supplied, measuring to $\frac{1}{5000}$ millimeter ($\frac{1}{125000}$ in.), as well as various other instruments for conducting the experiments. One series was designed to test the truth of Wöhler's three laws, which are:

(1) Fracture may be produced by the continual repetition of oscillating stresses, all of them much below the breaking stress. It is the differences of strain, defined by the extent of the oscillations, which then produce fracture.

(2) The absolute value of these stresses only enters into the question so far that the greater this value the smaller are the differences which will finally produce fracture.

(3) When the resistance of a material to one form of stress has been found by experiment, its resistance to all other forms can be deduced by calculation.

The author's experiments have confirmed the truth of the first law. With regard to the second, they are not yet complete. They do not agree with the third, inasmuch as experiments on transverse strain showed a much greater tensile resistance in the most heavily strained fibre than that given by direct experiments on tearing. Again, on comparing experiments on Krupps's axle steel, made in 1863 by Wöhler, and in 1873 by the Author, it appears that in the interval the material had been greatly improved in its resistance to the ordinary stresses of axles, but had diminished in its resistance to direct tension.

This latter is, of course, no real defect, and is, no doubt, due to an alteration in chemical composition; but it shows that tensile tests alone will not indicate the character of a material, and also how necessary it is frequently to repeat such experiments.

The Author has further endeavored to investigate the connection between the appearance of fracture and the molecular changes, in pieces broken by repeated strains. His theory is that under such strains the texture of the metal is gradually changed from the crystalline to the amorphous. There thus arise different states of equal density of the molecules, each state having its own limit of elasticity. As the strains go on, these limits of elasticity are passed in the case of a continually increasing number of the molecules, and the piece is thus gradually weakened until rupture results. This he considers to accord with the molecular theory of Fourier and Redtenbacher, viz., that metals consist of crystalline molecules of attracting matter, each intermixed and surrounded with repelling ether. The action of strain would then be to break up the molecules into smaller and smaller elements. Hence is explained the fact that just at the point where rupture begins the fracture looks dull and amorphous (because the action has there been the most intense), while at a distance it is still crystalline. The rays, which are generally seen converging to this point of rupture, are due to a flow of surrounding molecules to the more heavily strained parts. In phosphor-bronze, broken by repeated strains, a flow of the phosphorus to the more extended parts is distinctly visible.—*Abstracts of Institution of Civil Engineers.*

RAILWAY NOTES.

We are informed that the directors of the Paris, Lyons and Mediterranean Railway Company, have decided to apply the Westinghouse brake over the whole of that immense system, and that a contract has been made with the Brake Company for the supply of the fittings for 1,500 vehicles as a first instalment. The cost of fitting the whole of the passenger engines and carriages will amount to about 8,000,000f. Our neighbors are settling the brake question in France in a much more business-like fashion than the authorities on our own railways, for the Westinghouse brake has now been adopted on lines having one-half —and by far the more important half—of the entire mileage of French railways, and as the Railway Commission is insisting upon what are virtually the conditions laid down by our own Board of Trade, there seems little doubt that the whole of France will be efficiently equipped long before our own railway magnates have done wrangling over the numerous inventions, both of their own and others, and which at present interfere with the settlement of the brake question in this country.

Breakages of Steel Rails on Russian Railways During 1879.—The statistical returns of the Russian Ministry of Ways and Communications give the following interesting information on the breakages of steel rails on Russian railways during 1879. Up to January 1, 1880, on all lines, the length of which amounted to 24,019 miles, 9,730 miles of steel rails had been laid. The total length of the Russian railways, taking in consideration station sidings, was in 1879, 19,200 miles, and the breakages of steel rails during that year were as follows:

Months.	Total No.	Months.	Total No.
January	639	July	247
February	598	August	156
March	854	September	214
April	235	October	328
May	235	November	341
June	160	December	692

The best rails, judging by the small quantity broken, were of English manufacture, namely, those from Messrs. Brown, Bayley & Dixon, Sir J. Brown & Co., Cammell & Co., and the Barrow Hematite Iron and Steel Company.

Writing on the manufacture of paper railway wheels, the *Paper World* says: "The paper is straw-board of rather fine texture. It is received in the ordinary broad sheets, differing in no particular from those used for straw board boxes or other similar work. These sheets as they come from the paper mill are square, and are first cut to a circular pattern. This is done on a table with a knife guided by a radial arm. A small disc is also cut from the center of the sheet to admit the wheel center. The paper has now to be converted from loose sheets into a compact, dense body, capable of withstanding the tremendous crushing force to which it will be

subjected in the wheels. This is accomplished as follows: Ten sheets are pasted together, one upon another, making a disc about ¼ in. thick. Enough of these discs having been prepared to fill a powerful hydraulic press, they are subjected to a pressure of 1800 lbs. per square inch. When removed, the discs are hung on poles in a steam-heated loft and left six days to dry. Thicker discs are then made, each formed by pasting together two or three of those already finished. These are pressed and dried as before, and the process is repeated until a block is built 4 in. thick and of about the specific gravity of lignum vitæ. After each pasting and pressing six days are allowed for drying, and when the block is complete it is left in a drying-room until thoroughly seasoned. The next operation is that of turning the paper blocks to fit the steel tires and iron centers. This is done in lathes in the same manner as if the material worked on was tough wood. A bed or recess is worked out for the web of the tire to rest in. The block is then painted, and is ready for its place in the wheel."

THE London, Chatham and Dover Railway Company has not, we believe, made any promising announcements as to new station accommodation. With the inclement weather which now prevails an ordinary dry station is not the most desirable place to shiver away a half hour, but on the barns of stations with which the passengers are provided by the Chatham and Dover Company, even near London, words will not do justice to the outraged feelings of some of their passengers. It is therefore no desirable thing that passengers should be made to wait unnecessarily on the platform of such places. The Chatham Company has, however, issued a regulation that the gate entrances to some platforms shall be closed as soon as certain trains are due. No objection whatever can be made to closing these gates when a train is in sight or even signaled, or at any time if notice is given that it will be done, but closing them when a train is due involves discomfort to passengers. At the stations where there are two or three departure platforms this is especially the case during bad weather when rails are in bad condition and all trains are or are liable to be more or less late, for a passenger goes on to a platform, say ust before a train is due. He finds that the train is not even signaled, and thinks he will be able to take a train signaled at another platform. He leaves the first platform and goes to the second only to find the gate closed. Finding this he goes back to the first platform only to find that though the train is, as he knows not even signaled, the gate is shut. This train is late, perhaps very late, and the passenger waits until it comes in and goes, which he may have the pleasure of seeing it do. Then he may wait for another train not yet due, so that if he has patience he has time to sit down—no he cannot sit down, because the seats not occupied by the other passenger, who sits in a mackintosh lost in a reverie on railway pleasures, may be wet; but he can stand and think of the great difference between the ordinary public mind and the mind that can master the mysterious reasons of railway sages. At a station with only one platform such arrangements would be worse. A passenger arrives at the usual time for a train, trains are late, and the last train has only just gone, the gate is closed because another train is due. The passenger therefore waits until that train comes in and is gone, and then waits, unless, after exhausting his stock of complimentary expressions, he goes and takes a cab, tramcar, or omnibus. This sort of thing would not be so bad if the company had some fine stations they wished passengers to look at, but with stations without sides and with sieves for roofs it's—well it is not nice.

ORDNANCE AND NAVAL.

ARRANGEMENTS FOR THE DEFENCE OF THE MOUTH OF THE WESER.—The armor-plated works for the defence of the mouth of the Weser will shortly be completed. One battery for nine 21 cwt. guns, and two forts containing 10 turrets, intended for 28 cwt. and 15 cwt. guns have already been constructed in accordance with the approved principles of the present day for coast defences. The armament of the above works will consist of 24 pieces.

The two new forts, situated one on the right and the other on the left bank of the Weser, are built on a sand bank. They are washed by the river at high tide, and are surrounded by inaccessible ground at low tide.

The fort on the left bank is armed with lighter turrets than the one on the right, and has arrangements for these being worked by hand. Ten men can cause a complete rotation of the turret, weighing 492 tons, in five or six minutes. However, by means of a special contrivance two men will suffice to bring this about. The guns, mounted on carriages for *minima* embrasures, are worked by hand power, and can be served quickly enough to fire a round in a minute and a quarter.

There is a steam engine (the *Allgemeine Zeitung* states that this engine is an hydraulic one) in the fort on the right bank, which can cause the three turrets, weighing 590 tons, to revolve simultaneously and give 17° elevation to the six guns in them.

The chill cast armor plates which protect the fortifications at the mouth of the Weser have an aggregate weight of 7,529 tons, they were supplied by the Gruson foundry, which has also arranged the sub-structures of the turrets, and provided the ammunition lifts and the carriages for the *minima* embrasure. These armor-plated structures have one great advantage over those hitherto constructed in Europe. Thus, if a piece is struck and rendered unserviceable by an enemy's projectiles in English, Belgian, or other turrets, it has to be left in position till the end of the action, and you are deprived of its fire. In the Weser turrets, on the contrary, a certain apparatus allows the injured piece to be rapidly removed and immediately replaced by another which will continue the fire. Before being consigned to the mili-

tary authorities the forts will be subjected to experiments intended especially to test the armored turrets and the guns.

Remarkable practice has already been made with the 28 cwt. guns. Although the maximum charge of 58 kilos. of prismatic powder was employed, the precautions taken at first to fire by electricity and remove the detachments from the turret were soon found to be superfluous. In fact, thanks to the small size of the embrasure, which is just large enough to allow of the passage of the muzzle of the gun, the powder gases cannot enter the turret, and are consequently not offensive to the gun detachments.—*Allgemeine Militar Zeitung and Neue Frankfurter Presse.*

RUSSIAN COMPOSITE 8-IN. SIEGE GUN, CAST (IN STEEL) AT THE FACTORY OF OBOUKHOFF.—The gun consists of:

1. An inner tube of steel (3.8 m.) containing rifling and chambers.

An envelope consisting of two parts:

2. One the breech and trunnions.
3. The other the muzzle part.

The first of these two travels on the siege carriage, and is united to the other by a ring screw collar.

There are two other small pieces.

The weights of the five pieces are as follows:

1. Inner tube	541
2. Breech	2904
3. Muzzle	1826
4. Screw Collar	98
5. Breech piece	299
Total	5668 kilos.

The interior tube is carried in a stiff-covered box.

The gun was put together and placed at Globosia, opposite Rustchuk, in three hours, after dark, by a detachment of 20 untrained men.

The piece had been previously fired 130 times with 7.8 kilos. of prismatic powder.

Seven shots were fired on the 25th of August, 1877, at 2,900 metres, at an earth battery; one piece said to have been dismounted *

Six shots were fired at a gunboat on the 1st of September, one of which is said to have hit it.

On the 14th, 16th, and 19th November, 47 shots were fired at 4,900 yards against boats.

The gun stood together for three months, and was then taken to pieces with ease.

The Russians also made a 4-pr. mountain gun in three pieces of 98, 114 and 164 kilos. respectively.

BOOK NOTICES.

PUBLICATIONS RECEIVED.

THE TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS, containing:

"The Determination of Sulphur," by Thos. M. Drown, M.D.

"The American Bloomary Process," by T. Eggleston, Ph D.

"The Eighty-Ton Steam Hammer at Creusot," by J. A. Herrick, M. E.

"The Weight, Fall and Speed of Stamps," by H. S. Monroe, Ph. D.

"Rail Specifications and Rail Inspection in Europe," by C P. Sandberg, C. E.

"Cost of Milling Silver Ores in Utah and Nevada," by R. P. Rothwell, M. E.

"Chemical Reactions in the Bessemer Process," by Chas. F. King.

THE MONTHLY REPORT OF THE WEATHER BUREAU for November.

MODERN ARCHITECTURAL DESIGNS AND DETAILS, No. 4. New York: Bicknell & Comstock.

AMERICAN JOURNAL OF MATHEMATICS, Vol. 3, No. 2.

OFFICIAL GAZETTE OF THE UNITED STATES PATENT OFFICE, Vol. 19, No. 2.

NAVAL ENCYCLOPÆDIA.—Philadelphia: L. R. Hamersly & Co.

The Naval Encyclopædia is now complete. It is a royal octavo of 1170 pages.

This work has been prepared at a very large cost of time and labor, making it probably the most costly work ever prepared for the naval profession in this country.

The following summary of contents of the book will give an idea of its character and value:

I. A complete Dictionary of Nautical Terms and Phrases.

II. Biographical Notices of Distinguished Naval Officers of our own and foreign services.

III. Special Articles, including in their scope the entire range of Modern Naval Science, prepared expressly for this work by officers and others of recognized ability in their respective fields of discussion, and comprehending the freshest and most authentic information attainable respecting the several subjects treated.

IV. A Gazetteer of the principal Naval Stations and Seaports of the World.

V. A Supplement containing concise Records of Living Officers of the Navy, including Captains, Commanders, Lieutenant-Commanders and Lieutenants, and Staff Officers of relative rank. The records of Flag Officers are included in the body of the work.

Of the value to the service and nautical men generally there can be no manner of doubt. The publi-hers look confidently for a generous response to this, their final circular, from the officers of the service whom the book is primarily intended to benefit.

STEAM BOILERS: THEIR DESIGN, CONSTRUCTION AND MANAGEMENT. By WILLIAM H. SHOCK, Engineer-in-Chief and Chief of the Bureau of Steam Engineering, United States Navy. D. Van Nostrand, No. 23 Warren street, New York.

*I think this is a mistake: some of the 8-in. shells lay unburst in the town in September, but I heard nothing of a dismounted gun, and I think I should have had there been one.

We may say at the outset that this handsome quarto reflects great credit on the printers and engravers concerned in its production. It contains thirty-six full page and double page finely-engraved plates, which are placed at the end of the volume, and 150 cuts inserted in the text. It is printed on fine calendered paper, and is altogether a triumph of American typography. The text is divided into nineteen chapters, whose headings alnoe indicate its scope, and the manner in which the various divisions of the subject are treated fairly entitle the author to say, as he does in the preface, that he has "supplied a long felt need in this particular branch of engineering and construction." His short introductory chapter tells us of the materials used in the construction of boilers in the earlier days of the steam engine, why copper was superseded by plate iron, the latest forms of boilers due to the introduction of compound and high steam pressure, the essential parts of a steam boiler, how infinitely forms may vary, the conditions which determine the features of marine boilers, and particularly those affecting boilers in war steamers. The general subject thus stated, he takes up "combustion" in a chapter which gives us the latest chemical knowledge of fuels and their constituents, the latest data on temperatures of ignition and the total heat of combustion. Taking in, as it does, all the facts relating to fuel as a source of power, it necessarily gives, with all the precision attainable, the figures for calculating the important elements of furnace draughts. He now proceeds to examine the "transmission of heat and evaporation," a most important consideration, for on the efficiency of the heating surfaces depends the rate of steam production, and so leads up to the latest direction which inventiveness in steam engineering is taking—namely, the use of superheated steam. Its economy of fuel is undoubted, and the only other question to be answered is that of "the bulk, weight and cost of the superheating apparatus or the labor and expense of keeping it in working order and its liability to derangement." The chapters on "Materials" is interesting even to the lay reader, who takes the slightest interest in metallurgy. The use of copper, brass, the invaluable phosphor-bronze, cast iron, wrought iron and latterly steel, which improved processes of manufacture have made available, is treated historically and scientifically, invaluable tables of weights of iron used for plates and rivets being appended. The chapter on "Testing the Material" and "Principles of the Strength of Boilers" involve matters of great moment to the profession, and not less to the public. We now come to the making of the boiler, and this is exhaustively considered in ten chapters, which take the engineer from the design on paper to the boiler set up and ready for its final tests. As indicating the minuteness of the details given we may say that these ten chapters on construction are divided into eighty-eight sections, which include a mass of tabulated data and mathematical formulas. "Tests, inspections and trial of steam boilers" is a chapter which again has grave interest ontside of engineering circles, for on the faithfulness and efficiency of the test life no less than property is almost always dependent. The difficulties in the way of a thorough test are often very great. There is, therefore, grave significance in the author's words:

"Boilers which are faulty in design or built of inferior material, or have had workmanship put on them, may stand the hydraulic test, but under the varying and continued strains of actual practice they will, sooner or later, develop weaknesses which seriously impair their life and safety. Grave defects may be hidden from view after a boiler is built so that they cannot be discovered by the closest scrutiny. Therefore, the inspection of boilers should commence with the process of construction, and should be repeated frequently during the lifetime of the boiler."

The tricks resorted to by boiler makers, such as punching the rivet holes too close to the edge of the plates when these happen to be cut too small, are here pointed out. The various kinds of tests and their relative values are minutely examined. "Management of Boilers" takes the engineer skillfully through this important portion of his duties and leads naturally to the consideration of "Causes and prevention of the deterioration of boilers." In general the deterioration arises from the accumulation of scale or sediment, from corrosion, fracture, burning or distortion of plates. These are generally traceable to defects of design, material or workmanship; to mismanagement, the use of sulphurous fuel or impure water and to galvanic action. In addition to this formidable catalogue the author says: "There are some destructive agencies at work shortening the life of boilers, the action of which is not fully understood; and instances of the rapid deterioration of boilers occur, from time to time, for which no definite cause can be assigned." Stationary boilers frequently last twenty years; the life of marine boilers ranges, under favorable conditions, from nine to twelve years, and in naval vessels is often limited to six years of use. The varying conditions of prolonged strain and protracted idleness, of frequent impossibility during long cruises on distant stations of regular cleaning and repairs, account for the shorter life of the war steamer's boiler. The closing chapter is devoted to a subject ugly in itself, but as it is one of the means by which the life of the boiler is determined, must have a place—namely, "Boiler Explosions:"

"It is," says the author, "of the gravest importance that the true causes of every boiler explosion should be clearly understood in order that their recurrence may be guarded against. The tendency to ascribe explosions to obscure causes rather than to regard them as the natural results of conditions which can be prevented by intelligent care exercised in the design, construction and management of boilers, has, no doubt, its origin in the desire to escape responsibility for the results of culpable neglect, and has been productive of much mischief by engendering carelessness on the part of owners and attendants of steam boilers."

It is not sufficient to show that a certain set of circumstances could exist in a case of explosion, but that they actually did exist. Several of the extravagant theories, such as sudden development of electricity, the formation and detonation of hydrogen and oxygen, the constituent gases of water, the instantaneous conversion into steam of large masses of water, and so on, are satisfactorily met and disposed of. Apart from external injury or violent concussion the explosion of boilers are generally traceable to undetected or unremedied defects in construction, or ignorance or carelessness of management, either in the boiler itself or the furnace chamber and fuel supply. We cannot follow this part of the subject further, but it has a vital interest that recommends it to the consideration of every person concerned in the ownership and management of boilers. We have, indeed, barely skimmed the work in giving our testimony to its great value and the labor and knowledge it represents. These only can be estimated by reading it carefully from cover to cover and knowing how far it distances any work of the kind which pretends to give information on the subject up to the requirements of the present day.—*N. Y. Herald.*

MISCELLANEOUS.

HERR VON BOGUSLAWSKI has been led, from a comparison of the results of recent deep sea investigations, to the following conclusions respecting the temperatures of the Atlantic and Pacific Oceans: 1. The water of the North Pacific is, in its whole mass, colder than that of the North Atlantic. 2. The water of the South Pacific is, down to 1300 meters—4225ft.—somewhat warmer than that of the Atlantic, but below the depth colder. 3. The bottom temperatures are generally lower in the Pacific than the Atlantic at the same depths and in the same degree of latitude; but nowhere in the Pacific are found such low bottom temperatures as in the Antarctic portion of the South Atlantic between 36 deg. and 38 deg. south and 48 deg. and 33 deg. west longitude, in which bottom temperatures of —0.3 deg. C. to —0.6 deg. C. have been measured. 4. In the western parts of the Pacific, and the adjoining parts of the East Indian Archipelago, the temperature of the water reaches its minimum at depths between 550 and 2750 meters—1787 ft. and 8937ft.—remaining the same from this depth to the bottom. In the whole of the Atlantic the temperature from 2750 meters—8937ft.—to the bottom gradually though very slowly decreases.

SOLIDIFICATION UNDER PRESSURE.—Walther Spring has investigated the phenomena of universal regelation, or, in other words, the property which the particles of solid bodies possess of uniting by cohesive action under pressure. The pressure in some of his experiments exceeded 20,000 atmospheres, but in the majority of cases from 2,000 to 3,000 atmospheres were sufficient to secure his results. He concludes that all solid bodies possess the property of uniting when they are in close contact. This property is more or less pronounced in different bodies, and it appears to be a function of the hardness. Soft bodies are easily soldered; hard bodies, with difficulty. There is, however, another element which influences the union, to which he gives the name of waxiness, and which is illustrated by Tresca's experiments upon the flow of solids. In every case the bodies which were submitted to pressure were changed into a denser variety; prismatic sulphur, for example, which has a specific weight of 1.96, was changed into octahedric sulphur, with a specific weight of 2.05. We may infer from this fact that the state which matter assumes depends somewhat upon the volume which it is obliged to occupy, through the action of external forces. These experiments seem calculated to throw new light upon some important geological questions; the layers of primary rocks, for example, may have resulted from the union of the grains of sand or mud which were borne along by the waters; the great pressure would have ground and thrust and broken and soldered them anew so as to give them the form which they now possess; faults and cleavages of every description would be comparable to the crevices of glaciers.—*Bull de l' Acad. Roy. de Belg.*

THE towers of Cologne Cathedral are now the highest in the world, the height they have attained being 5ft. higher than the tower of St. Nicholas Church in Hamburg, which has hitherto been the highest edifice. When finished they will be 51ft. 10in. higher. The *Cologne Gazette* gives the following as the heights of the chief high buildings in the world: Towers of Cologne Cathedral 524ft. 11in. from the pavement of the cloisters, or 515ft. 1in. from the floor of the church; tower of St. Nicholas, at Hamburg, 473ft. 1in.; cupola of St. Peters, Rome, 469ft. 2in.; cathedral spire at Strasburg, 465ft. 11 in.; Pyramid of Cheops, 449ft. 5in.; tower of St. Stephen's, Vienna, 443ft. 10in.; tower of St. Martin's, Landshut, 434ft. 8in.; cathedral spire of Freibourg, 410ft. 1in.; cathedral of Antwerp, 404ft. 10in.; cathedral of Florence, 390ft. 5in.; St. Paul's, London, 365ft. 1in.; ridge tiles of Cologne Cathedral, 360ft. 3in.; cathedral tower at Madgeburg, 339ft. 11in.; tower of the new Votive Church at Vienna, 314ft. 11in.; tower of the fine new brick-built Rath-haus at Berlin, 288ft. 8in.; towers of Notre Dame at Paris, 232ft. 11in.

THE death is announced of Mr. William Lassel, F. R. S., on the 5th inst., in his eighty-second year. He was an astronomer of unusual ability, and the inventor and constructor of astronomical apparatus of great importance. His attainments in astronomy and physics and mechanics enabled him to discern the requirements of the observer, and to comprehend and apply the conditions and principles involved in the construction of the things required.